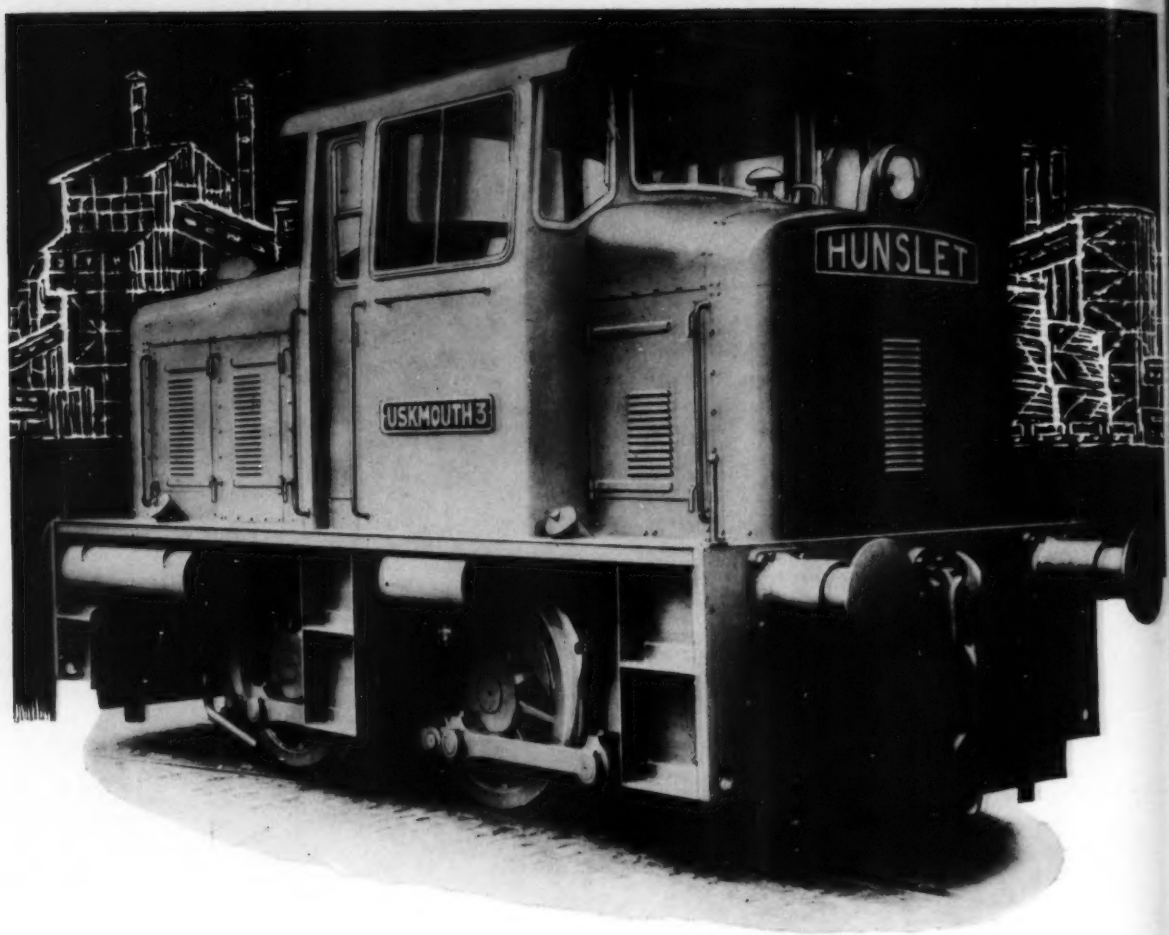
The Institution of Gas Engineers

JOURNAL

SEPTEMBER 1961
VOLUME 1 NUMBER 9



HUNSLET LOCOMOTIVES

for industrial use

Our standard range of diesel locomotives incorporating Hunslet patent hydraulic transmission, includes a type ideally suited to your application. The 153 h.p. 0-4-0 type 2-speed hydraulic locomotive is just one example of what we can offer in the medium power range. It is a QUALITY LOCOMOTIVE—the class of locomotive which is designed and built to give a life-time of trouble-free service.

THE HUNSLET ENGINE CO. LTD. LEEDS 10 LONDON OFFICE: LOCOMOTIVE HOUSE, BUCKINGHAM GATE, WESTMINSTER, S.W.1

H91

The Institution of Gas Engineers

Founded 1863 Royal Charter 1929

Patron : Her Majesty The Queen

President

T. C. Battersby, M.B.E., M.I.Mech.E., M.Inst.F.

Vice-Presidents

A. E. Haffner, Ph.D., B.Sc., M.I.Chem.E., A.R.C.S., D.I.C. W. Hodkinson, O.B.E., M.I.Chem.E.

Honorary Secretary

G. E. Currier, O.B.E., M.I.Mech.E.

Secretary

A. G. Higgins, M.Sc., F.R.I.C.

Assistant Secretary

J. R. Davidson, B.Sc.

Finance Officer — A. W. King, A.A.C.C.A.

Editor — Ben. Morgan, M.A.A.

Advertisement Manager — H. P. Howell

Librarian — D. P. Johnson, B.A., A.L.A.

JOURNAL

Vol. 1, No. 9 September, 1961

CONTENTS

	Page
The Industrial Use of Town Gas for Drying, Processing and Heating (with particular reference to radiant heat), by F. J. Brewer, A.M.I.Gas E., M.Inst.F. (Director and Divisional Manager), and H. N. Ballantyne, M.A., M.I.Gas E., Parkinson Cowan Industrial Products	605
The Thermodynamic Study of the Reforming of Hydrocarbons and its Application to Autothermic Generators, by J. Ribesse (Engineer) and C. Van Maele (Engineer), Distrigaz S.A. Belgium	631
Proceedings of Council	643
Binding of the Journal	643
News from the Gas Industry Overseas	644
In This Issue	645
Personal Notes	645
District Sections and Affiliated Associations:	
(*a*) Notes of Meetings	646
(*b*) Abstracts and Discussions of Papers	647
Forthcoming Meetings:	
(*a*) District Sections	650
(*b*) Junior Gas Associations	650
(*c*) Kindred Bodies	651
Institution Register	652
Library Accessions	652
Abstract of Paper to a Kindred Body	653
General Notices	653

The Institution of Gas Engineers as a body is not necessarily responsible for the statements made, nor for the opinions expressed, in the following pages.

Published by The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1

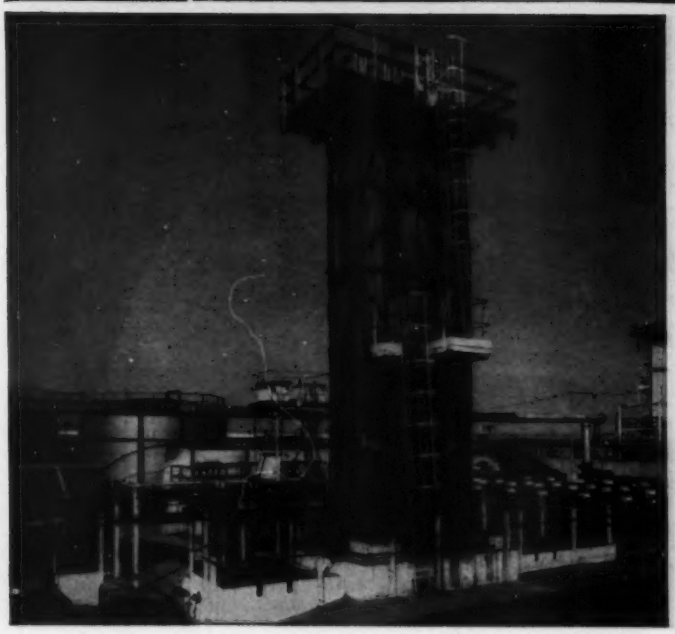
Subscription Rates: 7s. 6d. per copy, post free; £4 10s. per annum, post free.

Telephone: BELgravia 8266. Telegrams: Gasophaner, Knights-London.

BIOLOGICAL TREATMENT OF EFFLUENT

Simplex Surface Aeration Cone (Ames Crosta Mills & Company Ltd.)

Experimental Aeration Tower



The Southall Test Plant of the Gas Council for Experimental Work on Gas Works Liquor—

Engineered and Constructed by Woodall-Duckham

WOODALL-DUCKHAM

CONSTRUCTION COMPANY LTD

Woodall-Duckham House · 63-77 Brompton Road · London S.W.3

Telephone KENsington 6355 · Telegrams Retortical (Southkens) London · Telex 21488

A MEMBER OF THE WOODALL-DUCKHAM GROUP OF COMPANIES

THE INDUSTRIAL USE OF TOWN GAS FOR DRYING, PROCESSING AND HEATING

(WITH PARTICULAR REFERENCE TO RADIANT HEAT)

By F. J. BREWER, A.M.I.Gas E., M.Inst.F.
(*Director and Divisional Manager*)
and
H. N. BALLANTYNE, M.A., M.I.Gas E.
Parkinson Cowan Industrial Products (A Division of Parkinson Cowan, Limited)

COMMUNICATION No. 591

TABLE OF CONTENTS

		PAGE
I	Summary	606
II	Introduction and Short Glossary of Terms	606
III	Some Aspects of the Practical Utilization of Radiant Heat	607
	Section A.—Encouragement of Continuous Processes by the Use of Radiant Heat	607
	Section B.—Survey of Some Factors Affecting the Layout of a Product-finishing Plant with Some Work Study and Method Study Considerations	608
	Part 1.—General Considerations	608
	Part 2.—Calculations Involved in a Specific Example	611
	Part 3.—Short Description of an Actual Installation, Indicating Resultant Advantages and Savings	614
	Section C.—Some Lesser-known or Applied Applications of Gas-fired Radiant Heat Units in Industry, Agriculture, *etc.*	617
	New Hope for Agriculture	617
	Onion Drying	617
	Heating for De-infestation	617
	Brooders; Pig Breeding	617
	Frost Control in Agriculture	617
	Greenhouse Heating by Radiation	617
	Automatic Control of Rail Switches—Keeping them Free from Snow and Ice	618
	Possibility of Augmenting the Production from Paper-making Machines by the Use of Infra-red Radiation	618
	Rail Wagon Thawing	618
	Outdoor Gas-fired Radiant Heaters	618
	Textile Drying	619
	Rapid Carpet Drying	619
	Grease Burning	619
	Drying of Agricultural Sacks	619
	Section D.—Some Considerations in the Preparation of a Radiant Heat Scheme for Space Heating	619
	The Use of Gas-fired High-temperature Radiant Heaters in Dew-point or Humidity Control	621
IV	Conclusions	625
	Acknowledgments	625
	Literature References	625
	Presentation, Discussion and Reply	626

I SUMMARY

In this paper, an attempt is made to focus attention on some aspects of load building in the industrial fields of product finishing, processing and heating, and to provide a provoking, yet challenging, series of references to perhaps a more unusual approach under four main headings.

SECTION A.—The encouragement of continuous processes by use of radiant heat.

SECTION B.—A survey of some factors affecting the layout of a product finishing plant, with some work study and method study considerations.

SECTION C.—Reference to some lesser-known or applied applications of gas-fired radiant heat units in industry and agriculture.

SECTION D.—Some considerations in the preparation of a high-temperature gas-fired radiant heating scheme, with a section touching on humidity or dew-point control, and its use in industry.

In the authors' conclusions, there are observations that will no doubt give cause for reflection in so far as it contains advocacy of an organized investigation into the further uses of radiant heat in industrial fields and in particular a more liberal approach to the part that might be played by the gas industry in the recommendations to industrial consumers of the application or use of plant at its disposal.

II INTRODUCTION

The potential for load building within the fields covered by the title of the paper is so vast and so challenging that the authors make no apology for dealing only with a few aspects within each section. Considerations have been confined generally to light industry and agriculture, as on so many other platforms heavy industry has been given the prominence that it so rightly deserves.

The industrial gas engineer to-day is called upon to advise on an ever-increasing number of designs of plant, appliances and applications, and, whilst it is not unusual for like industries often to be located geographically near each other, the degree of specialization must vary inversely as the number and variety of applications of gas in industry grows.

Looking in from the outside, it is easy to see the problem as one would wish to see it. The shortage of trained, experienced industrial staff imposes a limit on load building —a limit that the industry can ill afford to suffer, as so many engineers look to the growth of the industrial load to absorb the additional capacity of gas-producing plants being installed in the major reconstruction programmes. In its turn, it implies a greater responsibility for the contractor to present to the industry as complete a picture of the requirements and suitability of plant for a given project, and there must be an accepted view that plant which is most suitable for the process in every respect is that which should be recommended. Unfortunately, it is not always so. Further, the industry must not only confine itself to load building *via* appliances; more than ever to-day " service " is an absolute priority—service in the technical investigation as to how, when and where the load may be used.

Equally enlightened executives in industry should not think in terms of lowest capital cost for an individual piece of equipment. This does not of necessity permit the optimum efficiency in, say, a product-finishing shop; it is the ultimate and final cost that determines the correct managerial decision as to which plant is installed and the shop layout to be employed.

What consideration does the industrial gas engineer give to the general development in production matters when recommending plant?

Improvements in production methods are rated high priority in the many varied industries that the gas industry serves. Radiant heat units, amongst others, provide with the detailed planning of an installation the possibility of the gas industry contributing to flowline, mechanized production and even automation in its simplest form.

Progressive thinking, synonymous with detailed layout and planning of installation to make the greatest use of all facilities in the factory or production unit, demands that the gas engineer does not deal in isolation with the possible load for a project. This matter is considered in some detail in the layout of a product-finishing shop. The load can be won or lost according to the amount of imagination, thinking and planning applied to the project. The advantages of combination of radiant heat and convection in some processes is apparent, and a reduction in drying time of, say, 10 per cent can have very considerable consequential advantages. Source temperatures should be chosen to suit the materials involved according to their absorption and reflection capacities.

Much work has been undertaken in the United States of America on infra-red energy produced by gas burners, and a few brief references thereto should at least open the minds of those associated with these aspects of load building to a realization that much can be done with existing equipment if only time, energy and enthusiasm could be harnessed in this direction.

With apologies to the specialist, the advantages of high-temperature gas-fired radiant heat for the purpose of " space heating " are defined for the young engineer; one approach to a heating problem (the industry has differing views on the correct method) is quoted, and it is worthy of note that, whilst every consideration may be given to all the facts available, the ultimate " consumer " may reject some considerations, whatever the scheme, in favour of a compromise.

In the matters of economy of operation of a given unit of production, there is less reason to expect a compromise if concrete economies result from such an installation.

A continental engineer designed and installed a heating scheme at a large rolling mill in the Ruhr incorporating humidity control to prevent rusting on steel sheets, which was the prime reason for installing the equipment. The capital and running cost is stated to be more than offset by the savings in steel spoilage.

A manufacturer of large sheet metal components, faced with a growing order book and limited space, already working two shifts, decided to modernize his plant. The combined efforts of product-finishing specialist and the consumer when applied work study was introduced led to complete rearrangement of the product-finishing shop. Flowline methods were introduced, two shifts reduced to one, and an effective labour saving from 32 men to 12 men in that department.

Load building can best be achieved by specialist knowledge of many industries, processes and applications and a breadth of experience beyond the complete technical knowledge of the design, commissioning and operation of the individual load-consuming appliance.

Short Glossary of Terms

Following is a list of terms used in this paper, together with definitions applicable to their use by the authors:—

Work study.—This is a generic term for those techniques, particularly method study and work measurement, that are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors that affect the efficiency and economy of the situation being reviewed, in order to effect improvement.

Method study.—A systematic recording and critical examination of existing and proposed ways of doing work as a means of developing and applying easier and more effective methods and reducing costs.

"Oven".—Equipment consisting of radiant heat panels built up in various forms for the stoving of paint within this oven. In addition to radiant heat from the panels, convection currents are also used—products of combustion.

Flash off.—Period of time between application of paint and commencement of stoving operation, to allow the evaporation of volatile materials from the paint film.

Water-wash spray booth.—Spray booth provided with water curtain over the inner back surface to remove paint from exhaust air.

Pyrostat.—An instrument for setting and indicating control temperature in an oven.

III SOME ASPECTS OF THE PRACTICAL UTILIZATION OF RADIANT HEAT

SECTION A

ENCOURAGEMENT OF CONTINUOUS PROCESSES BY THE USE OF RADIANT HEAT

So much has been written about the basic principles of radiation and its application in industry that the Authors are confining their comments to aspects not generally covered. For the purpose of this paper, since radiation can come from so many sources, two ranges only are dealt with, about 650°F source temperature *via* gas-fired infra-red standard panel, 36 in × 18 in (Figure 1) and the Schwank-type burner (Figure 2), effective size 7½ in × 5¼ in at approximately 1,500°F.

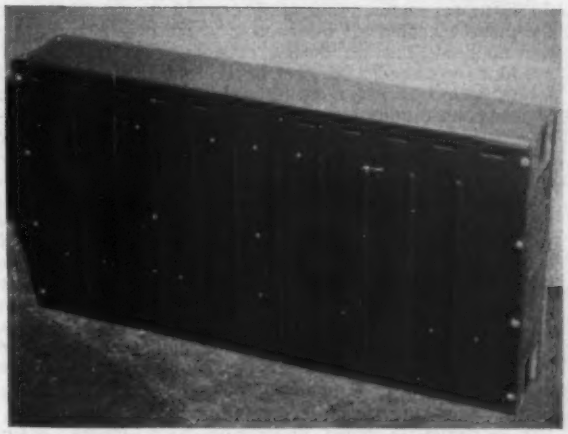


FIGURE 1.—*Gas-fired Infra-red Radiant Panel.*

With these two basic units, a very expansive field is opened for the application of radiant heat.

It is generally accepted in non-mechanized producing or processing units that handling charges are often a substantial part of the labour content of a product, and any steps that industry can take to reduce this handling must result in cost saving. For this reason, plant layout engineers strive to establish either continuous or semi-continuous conveyor production.

Radiant heat burners more readily provide the opportunity for converting batch production to continuous production. In certain continuous process work, it is common practice to dry by conduction. This contact drying

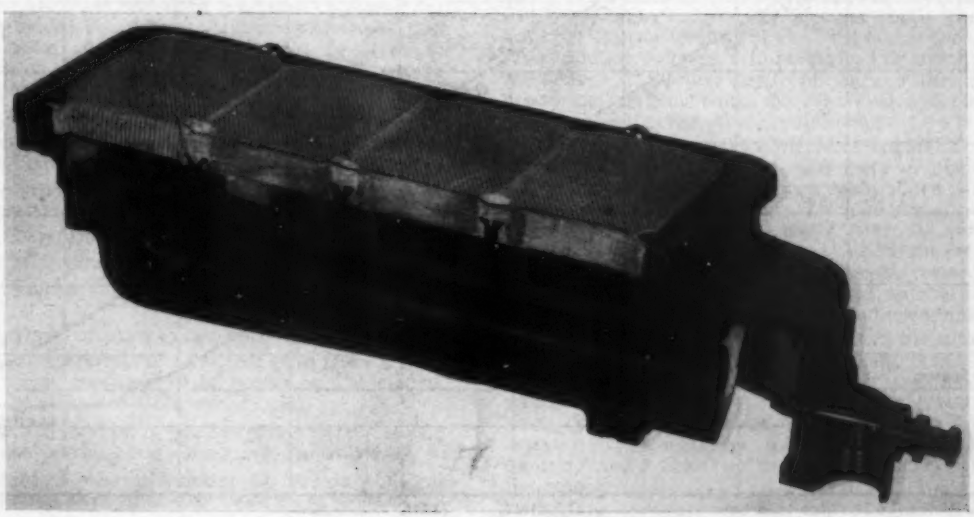


FIGURE 2.—*Section of Schwank-type Radiant Burner.*

usually entails large steam-heated cylinders over which passes a continuous web of the material to be dried. The capacity of such a machine is limited by the speed of drying, and this drying follows some well-defined laws. Figure 3*a* illustrates such a process. There is a short period after the commencement of the process where heat is passed to the material, but no drying occurs. This period may account for some 15 per cent of the total time. After this initial period, constant drying takes place, giving a curve of near-constant gradient. Towards the end of the constant-rate period, a gradual tailing off is apparent in the drying process. This then is drying by conduction and evaporation, two of the four means of heat transfer for drying. Radiation is a third method and can be used independently and be superimposed on the contact-drying cycle. This will shorten the initial period because the interchange of energy is almost instantaneous and could also shorten the tailing off of the complete process. A modest estimate would perhaps be a decrease in the initial period from 15 per cent to 5 per cent; a 10 per cent saving for such a continuous process is a very valuable gain. This decrease in time must be measured against running costs, but the increase in plant investment would be very little.

Radiation can then be successfully added to existing drying machines to boost production from existing plant already utilizing other forms of drying.

It can be seen from Figure 3*b* that, with the two temperatures under discussion, the energy emitted is nearly all useful heat. In the case of the source temperature of 1,500°F, a very small portion of the energy is visible light, and with the curve for 650°F there is no loss of heat energy within the visible spectrum.

Temperature (°F)	Maximum Wavelength Intensity (μ)	Total Radiation (Btu/ft²h)
650	4·7	2,600
1,500	2·7	25,500

SECTION B

SURVEY OF SOME FACTORS AFFECTING THE LAYOUT OF A PRODUCT-FINISHING PLANT WITH SOME WORK STUDY AND METHOD STUDY CONSIDERATIONS

In order that the various factors involved may be more clearly appreciated, this section is dealt with in three parts:—

Part 1.—General considerations.

Part 2.—Calculations involved in a specific example.

Part 3.—Short description of an actual installation.

PART 1.—GENERAL CONSIDERATIONS

Because of the present-day high costs of labour and factory space, radiant heat process equipment can very often be used to advantage in the installation of a continuous production or process line superseding a layout that might have been based on batch methods. It is necessary to study each heat-processing or paint-finishing problem from every possible angle. One has not only to

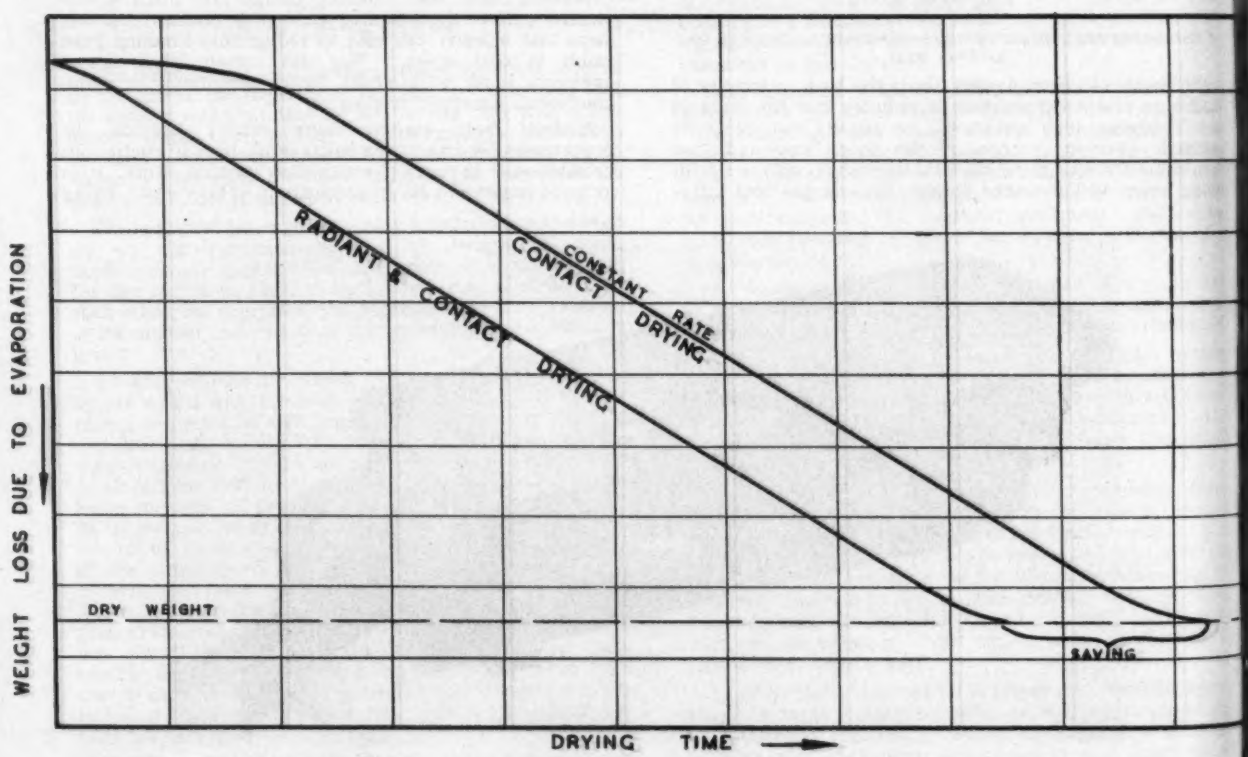


FIGURE 3*a*.—*Radiant and Contact Drying Curves for Continuous Process.*

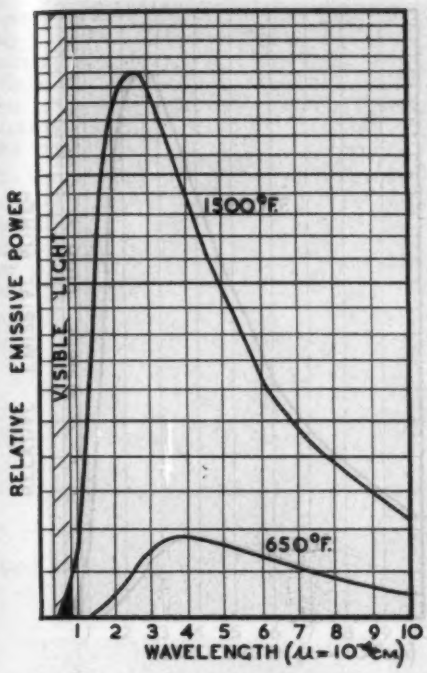


FIGURE 3*b*.—*Heat Emission Curves for Burners depicted in Figures* 1 *and* 2.

consider the "oven", but also all the ancillary equipment, particularly in the case of a modern paint shop. Work study must play an important part in the consideration of layout, in order that handling charges are reduced to a minimum and that the "oven" is used to the greatest advantage. Economies in handling charges can be very considerable, and basic fuel costs are often relatively unimportant, provided the complete layout enables the "cost per article" to be reduced to the minimum. In the initial consideration of a paint-finishing plant, it is necessary to have the following basic facts:—

(i) Size of components, gauge and type of material from which they are manufactured, and number per hour required.

(ii) The processes to which each component is to be subjected—
  (*a*) Degreasing.
  (*b*) Pretreatment, Phosphating,: *etc.*
  (*c*) Number of coats of paint (primer, finishing, *etc.*).
  (*d*) Types of paint to be used.
  (*e*) Temperature and time for stoving each coat. (This may need to be proved in a test plant, or estimated from experience.)

(iii) Size and location of site for plant; its relationship to the previous and subsequent operations.

(iv) Height of site and position of outside walls for planning disposal of flue waste gases and vapour.

(v) Any special requirements regarding the handling and hanging of components.

(vi) Direction of flow of work in relation to processes before and after painting or finishing operations.

(vii) Knowledge of manufacturing processes before and after painting or processing operations.

With these basic facts available, one can give consideration to the layout of the complete product-finishing plant. These basic facts are used in the following way:—

The gauge of the material being known and also the type of paint selected, establish processing time for degreasing, pretreatment, paint application and stoving.

Quantity and process time determines the length of plant required, and it is usual to find that the paint stoving time is the one that generally determines the process time.

Having established the stoving time, the most economic way of handling the components within the oven must then be determined, this is controlled by the size of component and the best way in which it can be hung on the conveyor to suit the various processes that follow and to use the plant to the greatest advantage, using, for instance, the minimum amount of floor space. As an example, take a washing machine: it is best hung in its normal position, since it is taller than it is wide, it can easily be rotated in that position and most of its surface area is receptive to radiant heat from the panels arranged vertically on both sides; it can be readily spray-painted either automatically or manually in this position; it is in a natural draining position during degreasing and pretreatment.

The hanging position having been decided, the centres at which the multiple components can be hung on the conveyor have then to be determined. This requires study of negotiation of corners, the rise and fall sections of the conveyor, whether these be into pretreatment tanks, degreasing tanks and the like, and to ensure that there is no fouling of the components one with the other or with the process plant.

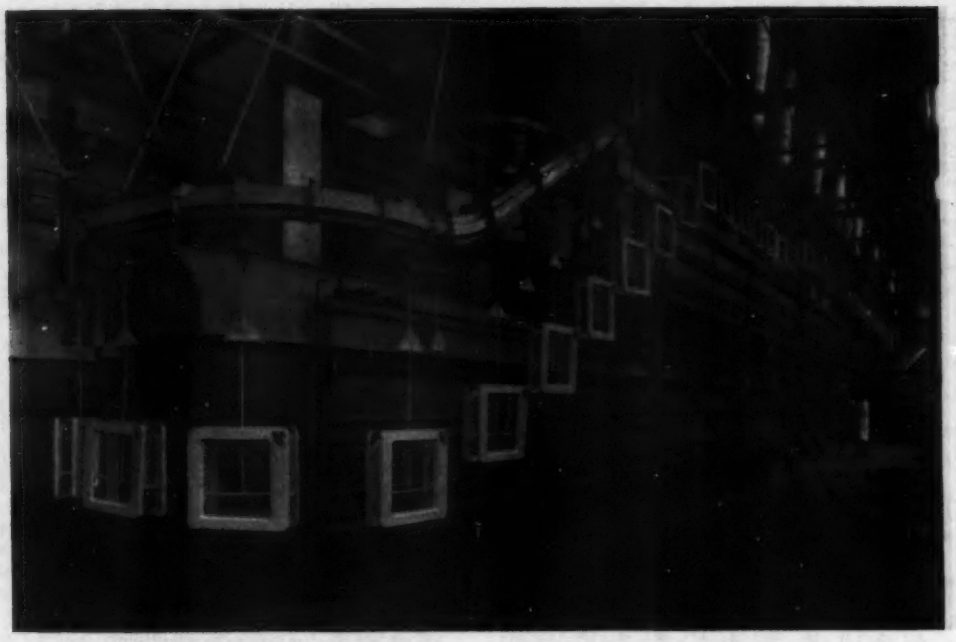
From this basis, one can calculate for the length of oven needed, taking into consideration the stoving time and quantity production required, and so from this the conveyor speed can be obtained.

It is then necessary to consider the other processes involved to ensure that the proposed conveyor speed, hanging centres, *etc.*, which have previously been established to suit the oven, will also be suitable for such processes and the equipment to be used. Presuming these are satisfactory, then the length of each of the pieces of processing equipment may be calculated and the relative position, each to the other, established.

With the addition of each of these lengths of plant and the necessary space between each piece of plant, a total length can be obtained, and this is really stated in conveyor length. Consideration is then given to the site available and to other controlling factors, such as position of entrance and exit of components to and from the product-finishing shop, direction of flow of work required within the product-finishing shop, position of suitable points for ducting from the paint spray booth and oven hoods.

It is often found that floor space available is inadequate to accommodate the plant on the floor, then, providing height is available, one must consider the possibility of mounting ovens, or even other pieces of plant, at high level. Such a consideration was necessary in determining a layout at the works of A.E.I.—Hotpoint, Limited, and Figures 4 and 5 show two ovens, double-decker, one above the other.

With the necessary rise and fall of conveyor, it can for instance, be recognized that two separate ovens may be necessary, one for primer coat, one for finishing coat, then



FIGURES 4 and 5.—*Double-decker Radiant Heat Oven for Drying Paint on Washing Machines.*
(Courtesy A.E.I.-Hotpoint, Limited.)

it may be advantageous to mount the finishing coat oven above the primer coat oven, in which case the mounting framework from the lower oven can be extended to provide that for the upper oven.

For ease of control and regulation and in order that temperatures of individual panels or banks of panels can be checked, an instrument panel as shown in Fig. 6 provides the central control.

PART 2.—CALCULATIONS INVOLVED IN A SPECIFIC EXAMPLE

For this example, the paint finishing of kitchen cabinets has been used.

Production 600 per 40 hr week, allowing for possible increase in production of one-third during the first 18 months of production.

Components:

Body: 3 ft 3 in high, 2 ft 9 in across corners, 24 in wide, 23½ in back to front.
Material: 20 swg mild steel.
Plastic top rim added on assembly.
Finished one coat primer, one coat finish.

Plinth: 24 in wide, 23½ in deep back to front, 1½ in high. This is not required to be painted on the outside edge but stainless steel "edging" strip added on assembly.
One plinth per cabinet.
Material: 22 swg mild steel.
Finished one coat primer, one coat finish.

Shelf: One per cabinet, ½ in deep pressing.
Material: 22 swg mild steel.
Finished one coat primer, one coat finish.

Door: 3 ft 1 in × 22 in × 1 in—one per cabinet.
Material: 20 swg mild steel.
Finished one coat primer, one coat finish.

All components to be degreased, phosphated, cold and hot rinsed and dried prior to painting. At present, these operations are carried out in dipping tanks. The customer requires good, durable, high-gloss finish to enable cabinets to match other domestic appliances, e.g., refrigerators, washing machines, *etc.*

Standard colours White and Cream.

Area allocated for new paint finishing plant, 60 ft × 32 ft, but every endeavour should be made to reduce this area.

Components to be hand-sprayed; electrostatic spraying application will not be considered until production is considerably increased.

Considerations in Planning Layout (Figure 7)

As a continuous process and to reduce handling of components, spray painting should be carried out when the components are suspended on overhead conveyor. It is important that each item is examined to determine how it is best suspended from the conveyor to enable it to be sprayed.

Cabinet

This is best carried in a vertical position; it will take up least space on the conveyor, has a uniform shape for rotating, has access for painting inside through door position.

Doors

These to be carried three per jig, to form a similar shape to that of the cabinet.

Plinths and Shelves

These can be carried to form a similar shape to that of the cabinet, six per carrier, two rows high.

FIGURE 6.—*Instrument Panel for Centralized Control of Gas Drying Ovens.*
(Courtesy A.E.I.-Hotpoint, Limited.)

The conveyor chosen for this particular scheme is completely articulated, has 8 in pitch chain, standard track radius of 3 ft 8 in or 2 ft 6 in for the vertical and horizontal bends. The standard sprocket is on a 90° drive unit, has 1 ft 9 in pitch circle diameter, and when dealing with this type of component it is necessary to ensure that the hanging centres are such that cabinets negotiate the corners without fouling, or, alternatively, other arrangements have to be made as detailed below. As the cabinets and components must be free to rotate to enable them to be sprayed, the minimum pitch that can be used is 40 in carrying centres. There is ample clearance when components negotiate a 2 ft 6 in radius bend or a 30° rise or fall sector of the conveyor, but on a 90° drive unit the components would catch, thus giving three alternatives:—

(*a*) To have a special, larger sprocket made, which would be costly and in all probability delay delivery.

(*b*) To fit a caterpillar drive unit; this drives the conveyor from a straight section of the chain. Again this is somewhat expensive.

(*c*) To arrange the 90° drive unit in such a position that the conveyor is empty when this corner is negotiated.

In this particular example, it was possible to use the third alternative.

The type of carrier required is one that can be either free to rotate by hand during spraying, rubbing down and inspection operations, or it may be fixed so that the cabinet is square on the conveyor prior to passing through the silhouette at the entrance and exit of the spray booths and ovens, or negotiating a rise-and-fall section of the conveyor. For very little extra cost, these carriers could be arranged to index through 90° every 1 ft 4 in forward travel of the conveyor through the ovens. This is not essential, but it is an advantage on high quality painting finishes on work of this nature. (This type of carrier and conveyor is suitable for use with electrostatic paint spray applications should the customer eventually wish to install such equipment.

Stoving Time

This is to be determined by experience or test. In the scheme under review, it is suggested that a stoving time of 12 min be allowed for the initial production of 600/week, and when production is increased by one-third reducing to 8 min. Provided spray booth, flash off and cooling is adequate for the larger production, no further plant would be required for this production increase. The reduced stoving time of 8 min is in no way critical for the radiant heat oven, as the oven would still not be working at maximum temperature.

It should be appreciated that, if the consumer does not wish to invest in full capital expenditure immediately, a smaller oven can be utilized at lower immediate capital cost, and extended at a later date when production increases. This will, of course, probably cost more than had the job been planned for greater production in the first instance.

Percentage Stoving

This is a method of measuring the stoving effect on a paint on a particular article or part of an article passing through an oven on a conveyor, and gives a useful tool for establishing comparative results.

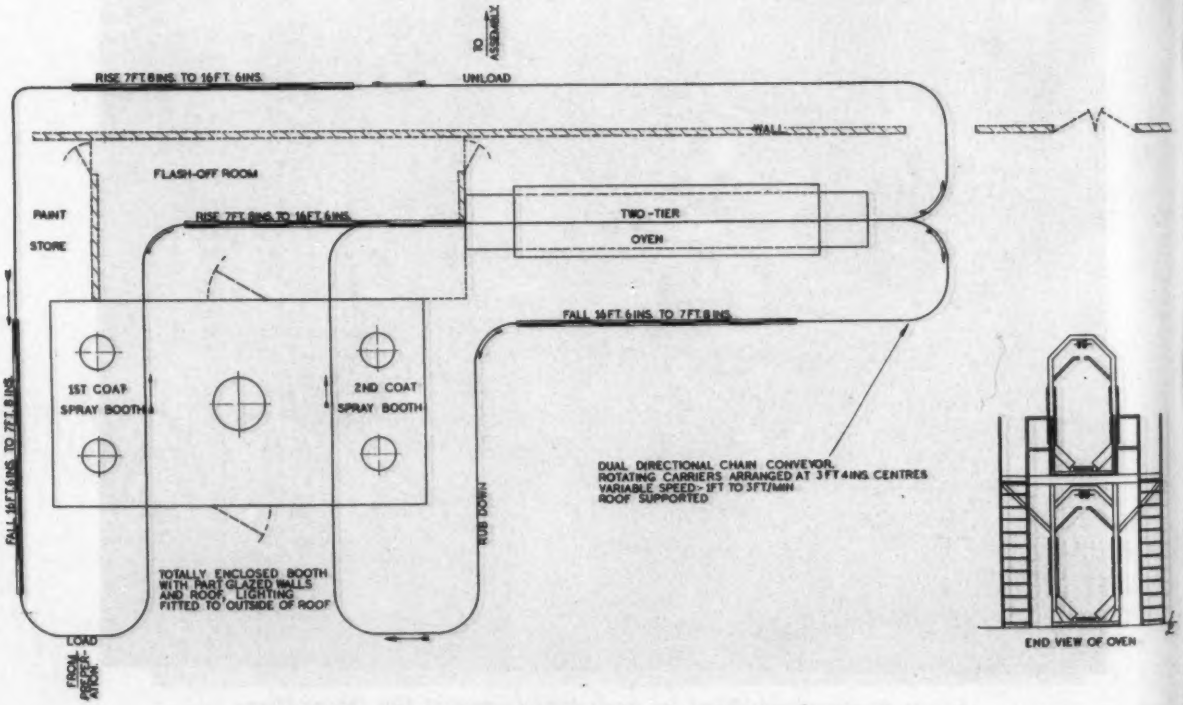

TO ASSEMBLY
RISE 7FT 8INS. TO 16FT. 6INS.
UNLOAD
WALL
FLASH-OFF ROOM
PAINT STORE
RISE 7FT. 8INS. TO 16FT. 6INS.
TWO-TIER OVEN
FALL 16FT. 6INS. TO 7FT. 8INS.
1ST COAT SPRAY BOOTH
2ND COAT SPRAY BOOTH
FALL 16FT. 6INS. TO 7FT. 8INS.
DUAL DIRECTIONAL CHAIN CONVEYOR ROTATING CARRIERS ARRANGED AT 3FT 4INS. CENTRES VARIABLE SPEED:- 1FT TO 3FT/MIN ROOF SUPPORTED
RUB DOWN
TOTALLY ENCLOSED BOOTH WITH PART GLAZED WALLS AND ROOF, LIGHTING FITTED TO OUTSIDE OF ROOF
LOAD
FROM PREPARATION
END VIEW OF OVEN

FIGURE 7.—*General Layout of Paint Shop for Kitchen Cabinets.*

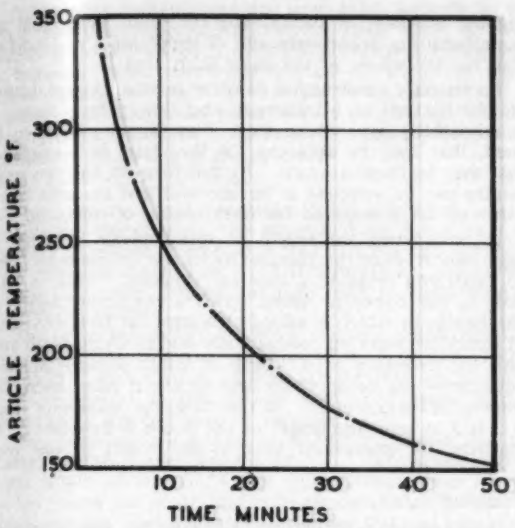


FIGURE 8.—*Curve for Calculation of Percentage Stoving.*

Two curves are required, e.g., Figures 8 and 9. The first is the stoving schedule, which is a series of points of combination of time and temperature to give the required degree of stoving, and, within limits, any of the time and temperature combinations can be used to give complete stoving. Too high a temperature may cause burning; too low may never stove at all. The temperatures are those measured on the article and not those of the conditions in the oven. These schedules can be supplied by most paint manufacturers. The second curve is constructed by measuring the temperature on the article—usually by a thermocouple with trailing leads—and plotting these temperatures on a time base.

To establish the "percentage stoved" under these particular conditions, the article curve is divided up into short periods of, say, $\frac{1}{4}$ min each and the mean temperature of each taken. The full time required at that temperature is read off the stoving schedule and the percentage stoved for that increment noted. For example, at 250°F, 10 min are required, so in $\frac{1}{4}$ min the paint is 5 per cent stoved. The total of these percentages gives the "percentage stoved". If this falls between about 80 and 200 per cent, the result will normally be effective stoving.

CALCULATIONS TO DETERMINE "OVEN", CONVEYOR AND SPRAY BOOTH SIZES

Oven length: Production 600 complete cabinets per 40-h week = 15/h.
Carrying centres 3 ft 4 in.
Stoving time is 12 min.

Cabinets: Consider a length of oven equivalent to the carrying centres 3 ft 4 in.
In 12 min, one cabinet must pass through this length.
Therefore, in 1 h, five cabinets will pass through every 3 ft 4 in of oven.
Therefore, oven length for 15 cabinets/h
$= \frac{15 \times 3\frac{1}{3}}{5} = 10$ ft.

Plinth: Six plinths every 3 ft 4 in every 12 min = 30 plinths/h every 3 ft 4 in.
Therefore, oven length for 15 plinths/h
$= \frac{15 \times 3\frac{1}{3}}{30} = 1$ ft 8 in.

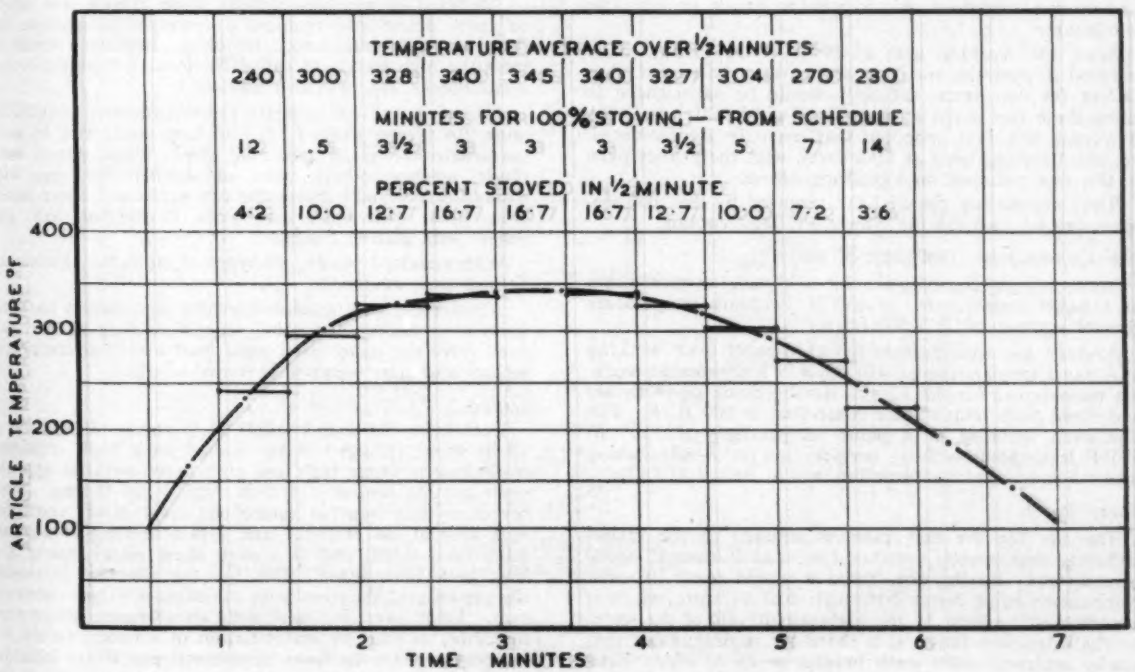


FIGURE 9.—*Curve for Calculation of Percentage Stoving.*

Shelves: As plinths, oven length 1 ft 8 in.

Doors: Three doors every 3 ft 4 in every 12 min. = 15 doors/h every 3 ft 4 in.
Therefore, oven length for 15 doors/h $= \frac{15 \times 3\frac{1}{3}}{15} = 3$ ft 4 in.

Total length of oven for one coat:—

	Ft
Cabinets	10
Plinth	$1\frac{1}{2}$
Shelves	$1\frac{1}{3}$
Doors	$3\frac{1}{3}$
	$16\frac{1}{3}$

Standard Panel lengths are 3 ft, therefore the actual length of oven required = 18 ft.

Conveyor speed to give 12 min stoving time through 18 ft oven $= \frac{1.5}{1.2} = 1{\cdot}5$ ft/min.

Conveyor speed to give 8 min stoving time through 18 ft. oven $= \frac{1.8}{8} = 2\frac{1}{4}$ ft/min.

Normal variable speed range fitted to this type of conveyor is 3:1. Therefore, if a speed range of 1 to 3 ft/min is chosen, this will cover both immediate production and future one-third increase.

Ovens

Each oven will consist of 36 standard 36 in × 18 in radiant heat panels built into two banks 3 ft 3 in apart, arranged three panels high, six panels long, bottom row inclined at 45°. Such an oven will give adequate coverage for the tallest components, i.e., plinths and shelves.

A top row of panels inclined at 45° is not needed since there is no large top surface to stove.

Maximum overall width of components is 3 ft, i.e., plinth and shelves; therefore, width between panels of 3 ft 3 in is adequate.

Since the working area of 60 ft × 32 ft has to be reduced if possible, and two coats are to be stoved, thus calling for two ovens, difficulty would be experienced in siting these two ovens at floor level within this area. To overcome this, it is proposed that ovens be double-tiered, i.e., the finishing oven at floor level, with the primer oven in this case mounted on a platform above.

Time negotiating rise and fall required by this arrangement can be used for the "flash off" and cooling.

Gas Consumption (500 Btu/ft³ gas)

Maximum gas consumption for a 36-panel oven working at a panel temperature of 650°F (without temperature control equipment) is 1,800 ft³/h.

Average gas consumption for a 36-panel oven working at a panel temperature of 450° to 475°F (estimated working temperature for the 12-min stoving time), correctly set and fitted with temperature controller, is 900 ft³/h. For one oven working at a panel temperature of 550° to 575°F (estimated working temperature for 8-min stoving time), average gas consumption would be 1,150 ft³/h.

Spray Booth

The site for the new plant is situated in the manufacturing department, not dust-free, and if normal open-fronted spray booths were fitted it would result in some components being rejected through dust and dirt, which is attracted on to them by the high-velocity air of the spray booths extraction fans. It is therefore recommended that totally enclosed water-wash booths be used, which have facilities for supplying filtered air, warmed if necessary, to give a slight positive pressure inside the booths, thus avoiding the necessity of partitioning the paint shop from the manufacturing department and of supplying a make-up air unit for the whole of the paint shop area.

To simplify construction of spray booths, extract ducting should be kept to a minimum and thus reduce costs. It is advisable, also, where more than one booth is to be used, that they be adjacent. In this case, it is suggested that they be front-to-front. By this method, the two spray booths can be assumed to be one unit and the area where make-up air is required for both booths is combined.

In considering the length of spray booths, one has to take into account the complexity of the components being sprayed, and estimate a time for spraying. This, in relation to the conveyor speed, gives a minimum length of the booth, to which is added clearance for free movement of operators working continuously and in an enclosed area plus the necessary extra length of booth to accommodate adequately the components and to avoid paint overspray fouling the booth ends. In this case, the maximum speed is 2 ft 3 in/min; the length of the booth is therefore 12 ft, allowing for maximum time in the booth of just over 5 min.

Flash off

Here again it is preferable to enclose the area to prevent settlement of dust and dirt on wet work, and to vent to atmosphere by natural-draught stack.

Flash off times vary from 3 to 10 min, depending upon the type of paint used, and often a compromise must be made, depending on layout and after consultation with the paint supplier.

Part 3.—Short Description of an Actual Installation, Indicating Resultant Advantages and Savings

Product: Office Metal Partitioning

The existing product-finishing shop layout was found to cause delays and required a conveyor to improve the flow of work and reduce handling. Improved finish to meet the high standards called for in luxury partitions for office blocks, *etc.*, was also wanted.

The range of components to be processed was fairly wide, the largest panel 12 ft 6 in long and 3 ft 6 in wide, constructed from 20 swg mild steel. Some panels were single, whereas others were of double thickness with insulating material between the two surfaces. Some panels were fitted with open wire work in the top half, and others with glazing fitments.

With standard panels, all types of uprights, fascias and fittings were required.

A complete new product-finishing installation has now been in operation for some time, consisting of two gas-fired infra-red panel oven units, two overhead chain conveyors and four water-wash spray booths.

Ovens:

Each infra-red oven consists of 48 panels (36 in wide × 18 in. high) arranged in two banks, each bank consisting of 24 panels, three high and eight long, with an approximate heating area of 4 ft 6 in high × 24 ft long. Since the plant has been in operation, sheet metal vestibules, 9 ft long at the entrance and 2 ft 6 in long at the exit, have been fitted, and two oven sheet metal inserts 2 ft long have been fitted. This has the effect of increasing the capacity of the oven with no increase in gas consumption. Each oven is fitted with an 18-point temperature indicator, so that, by manipulation of a rotary switch, the temperatures on the faces of selected panels are indicated on the instrument; temperature control equipment is also fitted.

All the gas supply pipes are sunk into channels in the floor and are, therefore, not seen. Each bank of oven panels is controlled by a constant-pressure governor and a butterfly valve controlled by an electronic pyrostat. Each pipeline serving a row of panels is fitted with a control cock, and each panel has its own cock. By this arrangement, adjustments of temperatures may be accomplished by the setting of the pyrostat.

Conveyors:

There are two dual-directional chain conveyors, one to handle the primer coat, the other to handle the finishing coat. The primer conveyor is 348 ft long and arranged in a rectangle 89 ft 9 in × 74 ft 6 in around the outside of the shop, with one side at high level to allow passage of fork-lift trucks.

The drive has a 4:1 infinitely variable speed-reduction gearbox giving a mean speed of 4 ft 6 in/min, and a range of 2 to 8 ft/min. Chain attachments are provided at 16 in centres, so that various sizes of components may be hung on the conveyor as required.

The finishing-coat conveyor is situated inside the rectangle of the primer line in an " L " formation, with a total length of 249 ft. Other general details are similar to the primer conveyor, and both are completely suspended from existing roof trusses, so that the floor is kept clear of supporting structure.

Spray Booths:

Four water-wash spray booths are installed, two being situated on each of the finishing lines. Each booth is 12 ft in width, 7 ft high × 8 ft overall depth and placed side by side, but facing in opposite directions. Exhaust from the booths is by top extract, using two 24 in diameter fans in each. The water pumps have a capacity of 250 gal/min, and the washing is by means of 35 nozzles. The ends of the booths are silhouetted with slots to allow passage of components.

Operation: (See Figure 10)

Components are loaded on the primer conveyor, which is travelling at 5 ft 3 in/min, and these travel through the spray booths. As these are facing in opposite directions, the operators each spray one side of the components. At this conveyor speed, the time for spraying is slightly less than 2 min in each booth, and it has been found to be adequate.

After leaving the spray booths, components are allowed to " flash off " for the next 63 ft (which represents 12 min) before entering the oven. Stoving time is approximately 4¼ min with the ovens operating at an average panel temperature of 500°F.

After leaving the ovens, the components travel 74 ft to the transfer-point, during which time they cool. At the transfer-point, the components are unloaded from the primer conveyor and inspected. If it is found necessary, a slight sanding operation is carried out and then the components are re-loaded on to the finishing conveyor.

On this line, the spray booths are exactly similar to the primer ones, and operations also follow a similar sequence, except that the " flash off " space is reduced to 42 ft (representing 8 min) and the cooling 95 ft.

Operators:

The total labour to operate the plant amounts to 12 and a foreman, being used as follows:—

Two men to load components on the primer conveyor.
Two men spraying primer coat.
Two men to unload from primer conveyor and load again on finishing conveyor.

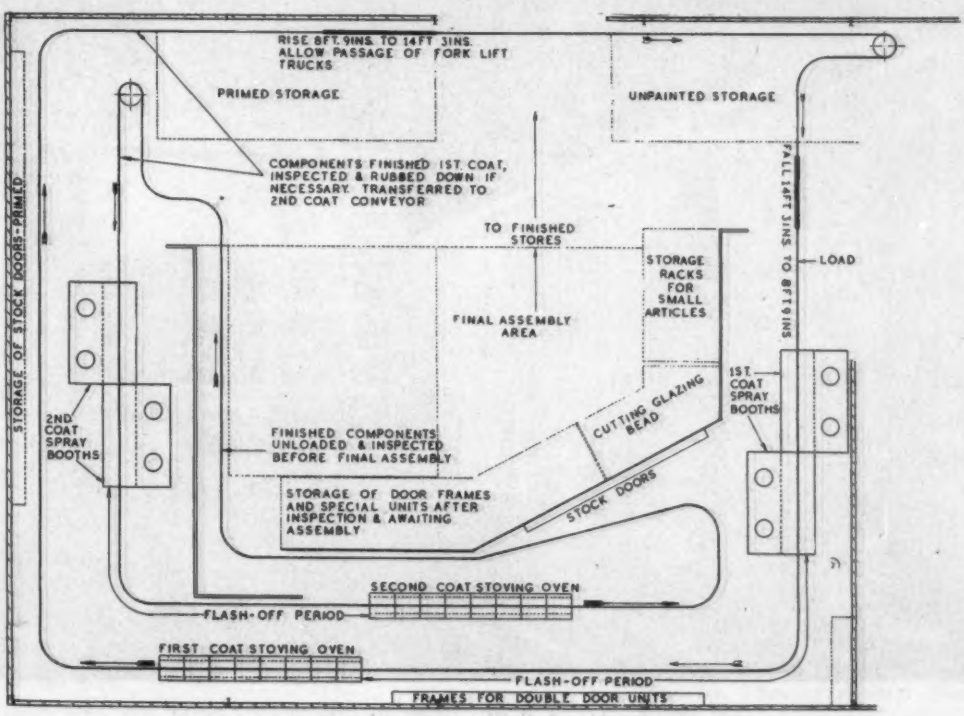

RISE 8FT. 9INS. TO 14FT. 3INS. ALLOW PASSAGE OF FORK LIFT TRUCKS
PRIMED STORAGE
UNPAINTED STORAGE
COMPONENTS FINISHED 1ST COAT, INSPECTED & RUBBED DOWN IF NECESSARY. TRANSFERRED TO 2ND COAT CONVEYOR
FALL 14FT 3INS TO 8FT 9INS
TO FINISHED STORES
LOAD
STORAGE RACKS FOR SMALL ARTICLES
FINAL ASSEMBLY AREA
STORAGE OF STOCK DOORS-PRIMED
1ST COAT SPRAY BOOTHS
2ND COAT SPRAY BOOTHS
CUTTING GLAZING BEAD
FINISHED COMPONENTS UNLOADED & INSPECTED BEFORE FINAL ASSEMBLY
STOCK DOORS
STORAGE OF DOOR FRAMES AND SPECIAL UNITS AFTER INSPECTION & AWAITING ASSEMBLY
SECOND COAT STOVING OVEN
FLASH-OFF PERIOD
FIRST COAT STOVING OVEN
FLASH-OFF PERIOD
FRAMES FOR DOUBLE DOOR UNITS

FIGURE 10.—*General Layout of Paint Shop for Office Metal Partitioning.*

One man sanding and assisting above.
Two men spraying finishing coat.
One man unloading from finishing conveyor.
One man assisting unloading, inspecting and stacking.
One man used as a stand-in spray operator.
One foreman.

The output of the plant is 24 panels (10 ft 6 in long)/h, and since it has been operating the rejects have been reduced to a negligible quantity. Colour matching on various components has improved considerably, and, as the type of product is manufactured in units for final assembly on site, this is a very important feature. The original plant to handle the finishing of components consisted of two dry spray booths, two triple-cased convection ovens approximately 12 ft long × 10 ft wide × 7 ft high. All the loading of ovens was carried out manually, and components were loaded upon special trucks for the stoving operation.

By this method, a component was required to be handled frequently during the finishing operation, as follows:—

(1) Placing into special spraying jig for spraying one side.
(2) Reversed for spraying second side.
(3) Loading on to truck for stoving.
(4) Unloaded for inspection and sanding (in special shops isolated from spray shop).
(5) Re-loaded on to truck.
(6) Unloaded from truck and placed on spraying jig for spraying one side.
(7) Reversed for spraying second side.
(8) Loading on truck for stoving.
(9) Unloading.

For this arrangement, a labour force of 18 men was required, and it was necessary to use a double shift to handle the production, and, therefore, it may be said that 36 men was the total labour force. They were used as follows:—

Ten spray operators.	One inspector.
Three oven loaders.	One labourer.
Two sanders.	One foreman.

Due to the fact that components with wet paint were handled, the number of rejects was relatively high and nearly all components required sanding after stoving of the primer coat. It was also difficult to ensure colour matching in final product and to obviate dust collecting on components whilst waiting for loading into the oven. It can be seen, therefore, that, by systematic study of what operations are required, of the load of work to be passed

FIGURE 11.—*Rail Wagon Thawing Plant.*
(Courtesy Perfection Industries, Cleveland, Ohio, U.S.A.)

through the product-finishing shop, and a work study of the various operations, it was possible to reduce the labour force from 36 men to 13, and the increased production was handled in a single shift whereas previously two shifts were necessary.

At this point, those associated with sales may well make the point that this has not necessarily contributed to load building.

There are two points of view:—

(1) A new layout could be replacing an old layout, using an alternative fuel.
(2) The new layout may be using less gas than the old layout.

Perhaps in the interests of efficiency, the new method has retained part of a load that otherwise might have been lost to an alternative fuel.

SECTION C

SOME LESSER-KNOWN OR APPLIED APPLICATIONS OF GAS-FIRED RADIANT HEAT UNITS IN INDUSTRY, AGRICULTURE, ETC.

New Hope for Agriculture[1]*:*

One of the foremost experts in research in the agricultural application of infra-red radiation is Dr. David Rosberg. With the pathologist at the A. and M. Experimental Station at Texas, he has been conducting experiments in this particular field for the past seven years, and it is thought that a great technical breakthrough in this field of investigation is imminent.

Onion Drying:

Dr. Rosberg[2] has attempted to prolong the storage life of vegetables. In times of glut, farmers could wait to obtain a better average market price.

Storing onions is not easy, because of neck rot, a fungus disease that, unless the onion is properly dried, might result in a large percentage loss of crop in a relatively short period of time.

Together with the United States Department of Agriculture plant pathologist, H. B. Johnson, Dr. Rosberg found that exposure of the onions to infra-red radiation for 3 min had the same effect as 4 h or more of forced-draught heat.

Heating for De-infestation[3]*:*

Cereal or grain growers and packers are faced with the impossible task of obtaining from grain elevators grains and cereals that are not infested with insect life such as beetles and weevils. Eggs laid by these insects are particularly troublesome, but it may well be possible to use gas-fired infra-red heaters to de-infest grain. A thin layer of grain or cereal passing under the infra-red heater at high speed could result in killing the insects and eggs.

Brooders; Pig Breeding:

The penetrating heat of infra-red radiation is known to offer great potential in chick breeding.

There may also be a move to battery production of pigs, and it is claimed that the number of gestations increases when pigs are continuously subjected to radiation at a wavelength of approximately 3 to 5 μ.

Frost Control in Agriculture:

Theoretically, infra-red radiation can be used to protect any crops against frost where the value of production is very high per unit area.

Loss of crops may well justify consideration of some protection in such cases.

Greenhouse Heating by Radiation:

Smallholders and farmers vie with each other to get their products to the market before the main crop is available.

Greenhouse heating by gas-fired radiant heaters has been studied at some length in the United States of America; the increase in humidity and carbon dioxide content is advantageous.

The growth[4] of plants is favoured by carbon dioxide if all other conditions are as normal as possible. Richer and

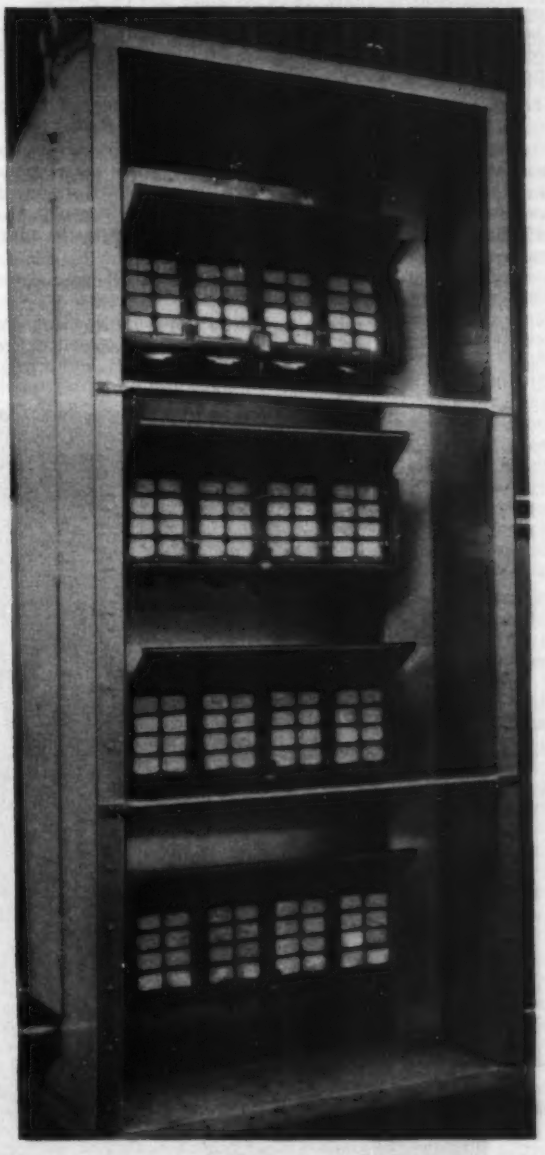


FIGURE 12.—*Schwank Radiant Burners Banked in Drying Unit for Thawing Railway Wagons. (See Figure* 11.)
(Courtesy Perfection Industries, Cleveland, Ohio, U.S.A.)

quicker fruit rudiments, earlier ripeness, stronger roots and stronger tissues are obtained by the addition of carbon dioxide; not only the concentration of carbon dioxide in the air, but that imparted by combustion of town gas is also an important contribution to plant growth.

Automatic Control of Rail Switches—Keeping them free from Snow and Ice:[5]

In the United States of America, gas-fired radiant heaters will automatically keep rail switches free from snow and ice. The heaters remain on until the last trace of snow or ice has gone from the area. Under rain conditions, with the temperature above freezing-point, the heaters remain off. If it is cold, but no icing conditions exist, the heaters remain off.

The Possibility of Augmenting the Production from Paper-making Machines by the Use of Infra-red Radiation:

It has been established that on pilot tests on an application to industrial parchment, the temperature at the entrance to the drying section without radiation was 68°F, and with radiation 113°F. This resulted in an increase in production of 28 per cent. Drying takes place generally in three stages:—

(*a*) Initial heating up to provide heat of evaporation of moisture.

(*b*) When the surface of a web is not entirely wet. At this stage, the greatest amount of moisture is taken out.

(*c*) When drying rate progressively decreases. At this stage, great heat input is required for small percentage moisture removal.

There are positive indications from tests made that gas-fired radiant heat units offer numerous application possibilities in paper-making and processing fields. Anxiety regarding fire risk can be allayed by confining the application of radiant heat to the wet end of the web and although adequate safety precautions could be provided at other sections it is most likely to be accepted if confined to the wet web.

Rail Wagon Thawing[6]*:*

Infra-red radiant heaters are being used very successfully for thawing out railway wagons containing materials such as coal, limestone, ores, *etc.* Such materials, when they have become wet and then frozen in transit, cannot be tipped until the wagon has been thawed. (See Figures 11 and 12.)

Outdoor Gas-fired Radiant Heaters

There has been only partial success in this country and on the Continent with outdoor heaters and their application. Recently, however, the Minneapolis Gas Company completed a very striking installation across the entire front of its office building. A sidewalk of about 150 ft is effectively heated by gas infra-red units, and during the past few weeks these have been subjected to one storm after another, and the equipment has had a very severe test.

FIGURE 13.—*Gas Burners for Burning Grease Off Steel Panels and Sink Units.*
(*Courtesy Edward Curran Engineering, Limited*)

As a result of this installation and the excellent results that followed, the gas company is now in the process of projecting the potential market for these outdoor heaters. Preliminary figures indicate that this is a large un-tapped potential market.

Textile Drying:

Before yarn is spun into cloth, it is subjected to many wetting and drying operations.

Infra-red radiant heat units emit wavelengths that are easily absorbed by water.

The drying or curing of rubber backing on continuous carpet production, and also the pile, has already been successfully done.

Rapid Carpet Drying:

Size is applied to the back of Wilton broadloom carpet of widths varying from 27 in to 15 ft. The size is 50 per cent dried by the application of intense radiant heat to the back of the carpet from underneath, causing steam to rise through the pile, untwist the wool and so raise the pile of the carpet.

The final drying takes place under jets of hot air. The advantages over the old method are speedier drying, better results and the most compact drying unit for the process in the country; the pile is not touched and therefore dries at 90° to the backing, giving a springy carpet with wear on the ends of the pile.

Drying by the new method occupies 10 ft 6 in length of radiant heat plant and 15 ft of air jets, a total length of about 26 ft.

The old method involved the use of some four steam-heated cylinders of 15 ft diameter, giving a total length of about 65 ft.

Grease Burning (Figure 13):

A conveyor oven is used for grease burning of 16 swg processed steel panels and sink units prior to pickling and vitreous enamelling.

The oven is 20 ft long×7 ft high, having 192 Schwank burners consuming about 24 therms/h. The Conveyor speed 2 ft 6 in/min.

Resulting from this installation is a considerable labour saving; formerly, four operators carried the items to an oil-fired furnace and then to the pickling bath. The new process requires only two operators.

Drying of Agricultural Sacks:

An oven used for drying agricultural sacks as part of a reconditioning service is made up of 36 panels in two banks, with the conveyor travelling at 3 ft/min and with a panel temperature 400°F. Very wet sacks are passed through the oven twice. 400 sacks are dried per 8-h day by one operator, at a labour and fuel cost of 2·6*d.*/sack.

Previously, the sacks were dried by an outside contractor at a cost of 4¼*d.*/sack.

It is not the Authors' view that these short references to one or more applications are new, but they serve as a reminder that much more work remains to be undertaken and results made known, in order that the gas industry may present to the respective sections of industry a clear picture and presentation of facts to support the exploitation of gas load in these fields.

Much valuable work has been done by the Gas Council's Industrial Gas Development Committee, but it is suggested that load building could and would increase at a faster rate if there were co-ordination and collation of facts such as manufacturers could use in the design of plant to meet specific requirements.

SECTION D

SOME CONSIDERATIONS IN THE PREPARATION OF A RADIANT HEAT SCHEME FOR SPACE HEATING

The advantages of the uses of high-temperature radiant heat for the purpose of "space heating" are often not appreciated to the full. Once again, it is the application and thought that go into the preparation of such a scheme that may well determine whether the load can be won for gas.

The industry has differing views as to the correct method of determining the number, size, type and positioning of radiant heaters. This paper does not attempt to lay down inflexible rules, as it is the Authors' opinion that neither the gas industry, the heating and ventilating industry nor building research organizations know the final answers to some of the problems that exist in planning such an installation.

Extensive use has been found in recent years for factory heating by radiation. It is probably the only method where partial heating can be applied to a large factory area and where the area around individual machines can be heated satisfactorily. The advantage lies in covering the selected area with radiant heat without resorting to heating the associated volume of air. Loading bays and other open areas can be treated successfully. Indeed, in America large open-air restaurants and sports arenas have been successfully heated, whilst in this country limited use has been made of the method to provide comfort in football and greyhound racing stands. (Figure 14.) Heating by high-temperature radiation becomes a serious consideration with the larger factory and air volume. Calculations revolving around the more conventional systems show that as factory volume increases so radiation becomes more and more attractive. It is found, generally speaking, where the height of factory building approaches 20 ft or more that this system scores over other methods. A correctly designed and controlled radiant heating scheme will give excellent comfort conditions in the larger factory bay, previously thought impossible or, at the best, very expensive to heat.

It is of interest briefly to recall the reason for providing heat during certain months of the year. It is a question of maintaining an artificial environment for working or comfort conditions. The question of a suitable environment for the particular activity is important. Everyone is familiar with conditions at, say, 65°F for office and home heating. This condition is usually maintained by air heating, and the walls, ceiling and floor temperatures are all very similar. These conditions suit the human body at rest or with reduced activity as the heat loss is made up of nearly equal amounts of radiation and convection, with a small loss through conduction. When human activity increases, this ratio of heat loss alters and the convection content rises greatly, hence one would feel comfortable with the surrounding air temperature at a much lower level, which greatly assists this loss due to convection.

The ideal environment when activities are high will be with a low air temperature, but with radiation at a level to counterbalance the radiant heat loss from the body. This ideal condition cannot be met by air heating as walls, floor, ceiling, *etc.*, must be at a temperature similiar to the air temperature. The radiant system is, therefore, basically correct. After all, these conditions are very similar to that experienced on a comfortable day, when the air temperature will be below the radiant temperature when the sun is visible.

In practice, it is impossible in factory heating to provide radiation without some air heating, indeed it is undesirable. Therefore, radiant heating is not an extreme approach in this instance as it is for outdoor heating. This balance of air temperature and radiation, coupled with the

type of work being done, is all important when designing a heating scheme for a factory. Internal air temperatures will vary from 30° to 60°F, and the radiation requirements accordingly. Their relationships are shown in Figure 15. These are dependent on such things as clothing, air movement and level of activity, but the feeling of comfort will fall within the comfort zone. The first step in considering a scheme must be to calculate the heat loss of the building, using the standard methods. Obviously, care must be taken in choosing the values for the transmittance coefficient U and to give a realistic assessment of the inside air temperature. This latter point is quite important. The advantage with radiation obviously lies in the fact that it does not appreciably heat the air volume directly; therefore, internal wall temperatures may be considerably lower than those experienced with more conventional forms of heating. Indeed, there is a school of thought in America advocating the use of a lower value for the transmittance coefficient when considering radiant heat, but the Author's own view is that the usual figures for this coefficient are adequate providing realistic temperatures are chosen.

Buildings can almost be classified as to their suitability to radiant heating by their structure and configuration. All buildings can, of course, be quite satisfactorily heated, but one finds that the larger factory bay is the real field for this system.

There is the problem of calculating the ventilation. The Author's experience is that there is a definite lack of information on the ventilation of large buildings, and various designers will use a variety of figures. The larger the building the larger will be the proportion of heat gained by the air volume, and this could be half of the total heat loss for a factory bay. This point, therefore, is of considerable importance when calculating the heat loss.

Actually, in a building where normal ridge ventilation is provided the air changes per hour will be reduced as the size of the building increases, and, with radiation as a means of heating, convection currents will be minimized and the air changes reduced still further.

Together with the heat loss at the lower air temperature and air changes, the minimum radiation requirements must be considered. This will vary with each application and will be generally not less than 20 Btu/ft²h, rising, as the air temperature falls, to perhaps 55 Btu/ft²h or more for the outdoor applications. The law connecting the radiant distribution and air temperature is exponential, but difficult to establish accurately because so much depends on the feeling of comfort between individuals under working conditions. For the more exposed cases, wind velocity is also a factor of importance.

Radiant space heaters can often be arranged in a variety of ways to provide the comfort conditions required, but further thought may be necessary if full effectiveness is to be utilized. It may be simple to provide an even distribution of heat at floor level from units mounted at high level. Unfortunately, under practical conditions, air is not

FIGURE 14.—*Gas Heating of Greyhound Racing Stands.*
(Courtesy North Thames Gas Board)

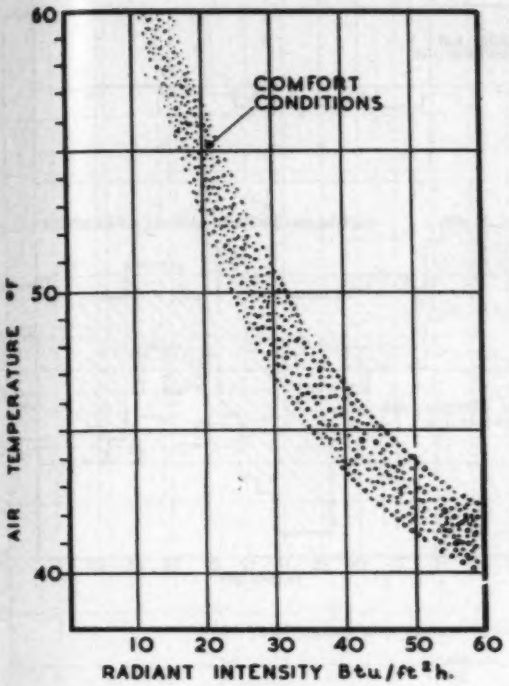


FIGURE 15.—*Radiant-intensity Curve for Comfort Conditions.*

necessarily a good transmitter of radiation. Factory air is seldom clean, especially at the higher levels, and the chief sources of absorption, apart from water vapour and carbon dioxide, are the metallic dusts of welding and grinding processes. For these reasons, placing of the heaters is most important, and the lower mounting height consistent with good distribution will often give the best results. Angle-mounted units provide this service, and it is interesting to note that even distribution can be obtained across a span of 100 ft from inclined units mounted at a height of 25 ft along the side walls. Inclined radiation in this manner has the additional advantage of covering almost completely the surface of a human being within its path.

The Use of Gas-fired High-Temperature Radiant Heaters in Dew-point or Humidity Control

An interesting application of radiant heat is its use in steel and aluminium warehouses. Here, there is often the problem of preventing corrosion on the stored sheets, and the classical method of recirculating the air volume through a heating and de-humidifying plant becomes uneconomical for such large volumes. There is also the time factor to be considered: humidity changes rapidly and the response of such a system may well be slow. Also to be considered is the problem of open warehouse doors and loading bays.

There is another approach, however, to these problems, which is to bring the surface temperature of the sheets above the dew-point of the ambient air. With good instrumentation and controls, a safety zone can be established and maintained between these two conditions. It is interesting to examine a record of such a system, which is shown in Figures 16 and 16*a*. It may be seen that in Figure 17 the critical hours are the early hours of the morning, accentuated in the spring and autumn months, when moist warm air will penetrate into the warehouse and cause condensation to form on the cool surfaces of the stored sheets.

It can be seen from the illustration that the outside humidity rises quite rapidly, associated with a fall in the outside air temperature. In association with this, the internal air temperature will fall, so contributing to the lowering of the surface temperature of the sheets, which is already falling due to radiation to the building structure. This latter loss is probably the greater of the two, depending largely on the construction of the building. By boosting the surface temperature with radiant heat during these critical hours, the sheets can be maintained at a surface temperature above the dew-point of the internal air, so preventing condensation. It is obviously necessary to establish the level of radiation required on the surface of the sheets and care must be taken to cover adequately all the exposed surfaces, thereby ensuring even temperature conditions all over the stack of sheets.

Figure 17 shows a typical chart of conditions inside and outside a steel warehouse in the Spring. The time scale is from 6 o'clock in the evening until 8 o'clock on the following morning. Both inside and outside air temperatures will fall continuously during this period and then rise slightly from daybreak. The outside humidity will rise and probably vary considerably during the night hours. This changing humidity will be reflected as a rise in the internal humidity as outside conditions infiltrate into the warehouse. The surface temperature of the stored steel sheets will fall during the night period, probably at a greater rate than the internal air temperature, due to losses by radiation to walls and roof, which will reach lower temperatures than the outside air if unlagged.

A safety zone is shown lying between the dew-point and surface temperature of the steel sheets. In the diagram, the unheated steel sheets just maintain this safety zone under these conditions, but superimposed is a point where conditions defeat the safety zone. If the conditions change during the early hours to give a dry-bulb temperature of 56°F and 90 per cent of relative humidity, the dew-point coincides with the steel surface temperature and condensation will form. Radiant heat will therefore increase the safety zone and in the example given will keep the sheets some 8°F above the dew-point. The safety zone should be at least 6°F above any possible dew-point temperature. A scheme of this nature has the additional advantage of use as a heating scheme during the winter months.

Controls for this type of installation must operate from the two important facts, namely, the dry- and wet-bulb internal air temperatures and the surface temperature of the sheets. Instruments are available that will integrate these values continuously and record on charts. The controls operate from the recording mechanism and actuate the heaters when critical conditions are approached. It is important that the temperature sensing device be mounted in such a way as to be truly representative of the surface temperatures. Two methods would be either to mount the sensing head on a plate of similar metal to that stored within the warehouse, or on part of the metal structure of the building, provided this is at a similar height and in a similar plane to the stored sheets. It is essential that the humidity sensing device be a stable mechanism.

Controls of this nature are best applied in zones. One zone may well be the area along the outer walls of the warehouse, which will be the first area to be influenced by the penetration of outside air. Instruments sited near the windows would obviously react quickly to changes in outside humidity conditions and a rapid response both by

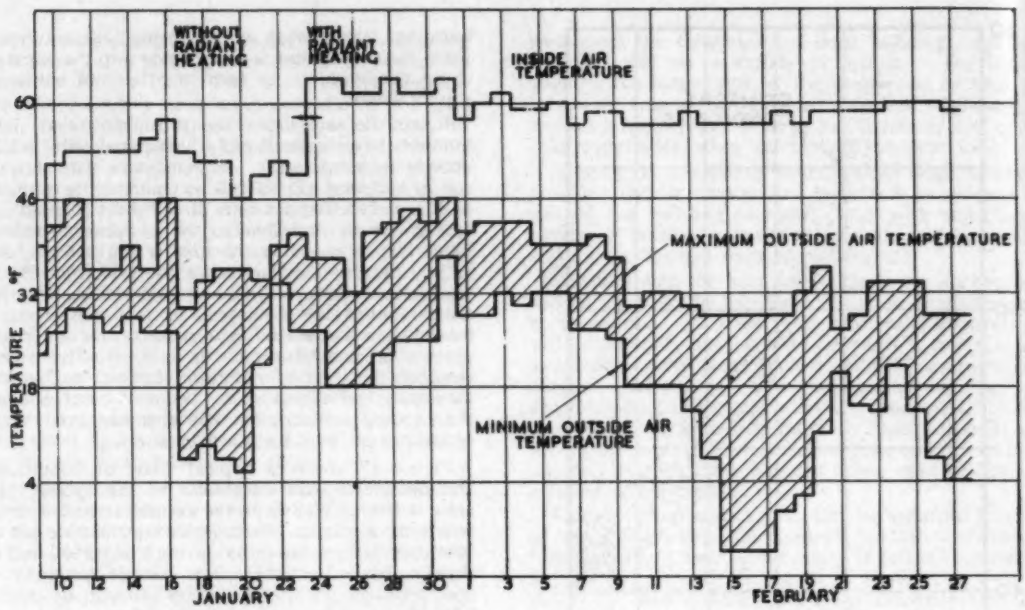


FIGURE 16.—*Effect of Radiant Heat on Temperatures in a Large Steel Mill.*

(*Courtesy von H. Goch, Dortmund*)

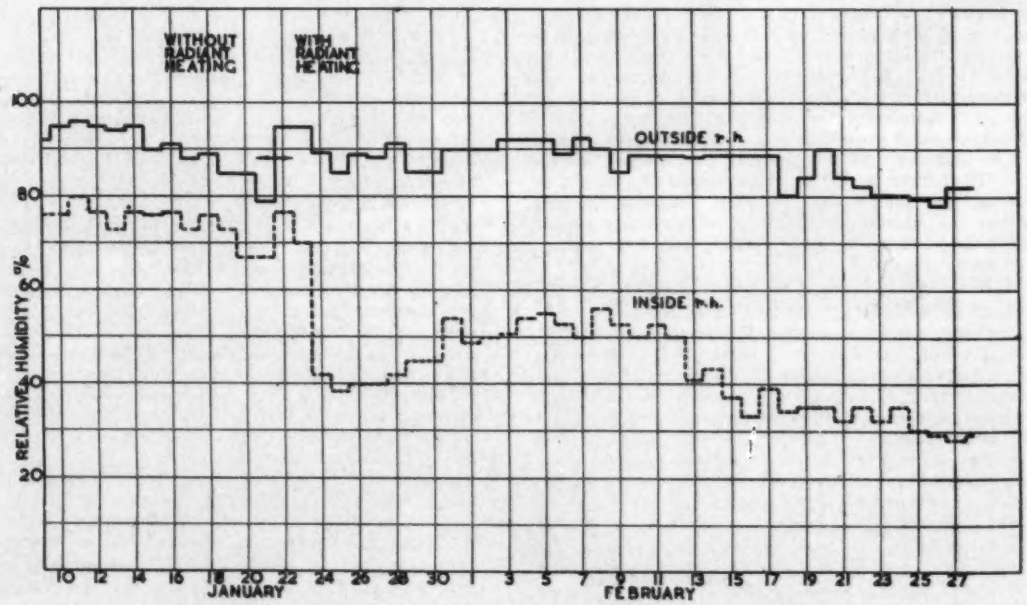


FIGURE 16a.—*Effect of Radiant Heat on Humidity in a Large Steel Mill.*

(*Courtesy von H. Goch, Dortmund*)

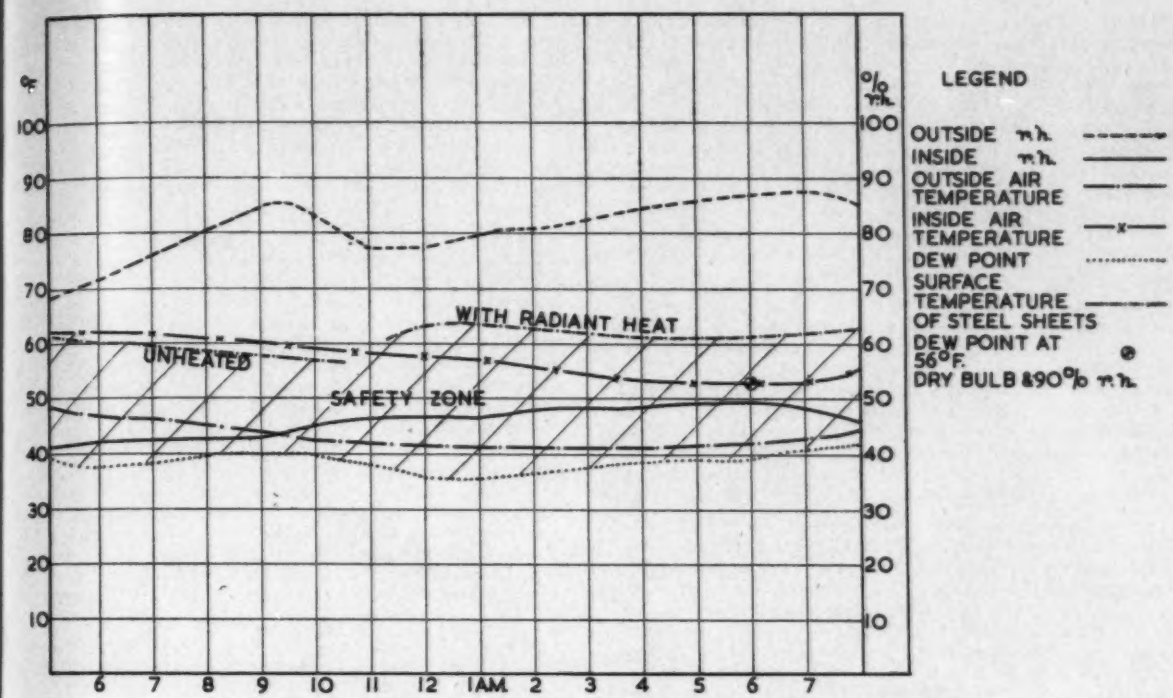


FIGURE 17.—*Temperature and Humidity Conditions in a Steel Warehouse.*

the instruments and by the application of radiant heat is necessary for this system. The second control zone could be established towards the centre of the building, where conditions would change less rapidly.

The intensity of radiation for such a control scheme would be higher than that normally required for general heating purposes, but the two schemes could be considered as a whole and the dew-point controls over-ridden by normal air temperature thermostats to give general heating during the day periods when condensation is less prevalent.

Some thought must be given to the ventilation and also to the construction of the underside of the roof, and it is possible that condensation will occur both here and on the building structure prior to forming on the surface of the sheets, and therefore cause damage to the stock due to dripping. There is a possible case for powered ventilation, associated with the dew-point controls. Using a humidistat for control will not give comparable results, but this instrument can prove useful where the relative humidity is of importance. This instrument can energize an electrical circuit on a rise of humidity above a pre-set value and will give a measure of control if the humidity is the critical value.

Controls:

It is not proposed to discuss in detail the individual controls fitted to each space heater, as these consist basically of a permanent pilot and a solenoid gas valve or an electrical ignition device, but to cover some aspects of the overall design of a control system for radiant space heating.

FIGURE 17*a*.—*Temperature, Humidity and Dew-Point in Central London for the Week Commencing 28th February, 1961.*

	6 a.m.			4 p.m.			8 p.m.			Midnight		
	Relative Humidity (per cent)	Outside Air Temp.(°F)	Dew-point (°F)	Relative Humidity (per cent)	Outside Air	Dew-point	Relative Humidity (per cent)	Outside Air	Dew-point	Relative Humidity (per cent)	Outside Air	Dew-point
Tuesday	90	42	39	57	50	36	76	50	43	93	49	48
Wednesday	84	48	43	71	54	45	78	52	45	73	49	41
Thursday	81	48	42	40	60	36	57	52	38	60	48	35
Friday	85	41	36	37	62	36	53	52	36	74	47	39
Saturday	90	43	40	40	64	39	46	56	36	76	49	42
Sunday	94	43	42	31	69	38	37	57	31	63	51	39
Monday	55	44	30	87	68	64	93	57	55	72	52	43

Figure 17*a* shows the variation in dew-point that does occur in the spring and autumn months: in this country. The change in humidity overnight is very rapid and dew-point at 8 o'clock in the morning can often reach a danger level within a badly lagged building.

As previously discussed, the ideal condition within a working area must fall within the "comfort zone", and, with this in mind, use has been made of the internal air temperature in the operation of the controls. This air temperature can, in this case, be considerably lower than that normally associated with comfort conditions in general heating projects: for instance, in a large workshop with manual work in progress, such as riveting, welding and heavy fabrication, air temperatures as low as 50°F are not unreasonable provided there is some additional radiation. In general, the Authors suggest that a figure of from 5° to 8° below the conventional air temperatures are quite compatible with comfort in a radiant heat scheme.

With these air temperatures in mind, use has been made of air temperature thermostats for the overall control of comfort, not because these controls are considered ideal, but because they are readily available, are well tried engineering components, are capable of adjustment and offer a cheap and ready means of control. Ideally, a system of control based on the principle of the eupathoscope would be necessary, but experience leads the Authors to believe that, with care in the design of the scheme, a normal air temperature thermostat is quite suitable.

These thermostats would be set at an air temperature below that experienced in normal heating practice and would control the output of the radiant heaters by simple on/off action. To avoid the undesirable physiological effect of all the radiant heat being extinguished at once, it is usual to couple alternate heaters to separate thermostats, so that, on a rise of internal air temperature, approximately 50 per cent of the radiant heat is extinguished, the remaining coverage of radiation being suitable for comfort conditions at this higher air temperature. Should the temperature continue to rise, the remaining heaters would be extinguished at a point where the second air temperature thermostat reaches a desirable comfort level. This is accomplished by wiring alternate heaters into two thermostats set at slightly different temperatures. A system based on two sets of air temperature thermostats mounted within a ventilated switchbox has been developed, which enables a flexible system to be designed.

Associated with these two internal air temperature thermostats for the control of a group of heaters may be an external air temperature thermostat. This instrument is mounted in a weather-proof box and is situated along the external walls of the building, approximately 5 ft from the ground, and is wired in parallel with the two internal air temperature thermostats. This instrument makes contact on the fall of temperature. This group of thermostats would control from the internal air temperature, but on a fall of external air temperature below a predetermined figure will allow the external air temperature thermostat to over-ride the internal controls, therefore allowing maximum heat to be available at a period when the maximum heat loss is taking place.

It has been found desirable to use this type of control on large, exposed wall surfaces, such as those encountered with large workshops. These buildings have huge air volumes and are often constructed of galvanized sheet steel or corrugated asbestos and are completely unlagged. The heat loss of such a place with the external air temperature below 40°F is nearly equivalent to that of an open space, hence the desirability of maximum heat input irrespective of the internal air temperature at the approach of a cold spell.

Referring to the internal controls once again, there are a variety of configurations that could be considered. Two systems will be discussed.

The idea of using internal air-temperature controls is obviously to give a measure of fuel economy and it is often stated that 1°F in excess of the desired air temperature represents 5 per cent of the total fuel bill. Therefore, to break the control system down into small units is very desirable and invariably the additional cost of the controls is more than offset by the saving. A point to be considered, therefore, must be the number of heaters to be grouped together in a control system, and these groups can be arranged in a variety of ways.

Firstly, for a large area (say 60,000 ft²) the coldest place will be around the external walls, and the system, which allows for the independent control of the centre area with additional controls around the perimeter will give a high measure of economy in running costs. In a number of temperature conditions, especially in the afternoons in the autumn and spring months, it will be found that the heaters along the periphery may remain "on", or alternate heaters be extinguished, as previously described, whilst the bulk of the heaters that cover the central area are "off" and will be "off" for the best part of the day. This condition could be accentuated where there are large areas of glass, so that the central area benefits from a solar heat gain. Also, of course, if the side walls of the building have large glass areas, those sides facing the sun will receive the benefit of heat whilst those sides in permanent shadow will possibly seldom reach the air temperature set on the thermostats. Again there is a case for using external air temperature thermostats for these exposed walls.

Secondly, there is scope for co-operation with planning engineers in designing a heating scheme of this nature. A planning engineer can often produce a drawing that shows working areas for different types of activity and it may be that a heating adviser can score by so arranging his devices that these different activities are controlled individually, thus giving maximum flexibility when selecting heating for overtime work. Radiant heat is an ideal application under these circumstances as it is perfectly feasible to heat, say, 20,000 ft² in part of a 60,000 ft² factory that is occasionally used for overtime. Controls of this nature can be designed so that a large panel gives a diagrammatic representation of the activities of heating for working area, so enabling precise selection of heating for overtime work and any variation in the working pattern in the shop. Such a control panel is illustrated in Figure 18.

All the above thermostatic systems of control can be coupled with timing devices so that a completely automatic space heating scheme can be offered. This scheme therefore incorporates all the advantages of radiant heat; it will operate to a precise working schedule that can be exactly the same as the working hours of a shop; selection of overtime is precise, the controls re-cycling and re-setting themselves for an automatic start on the following day after overtime working; any of the working sections can be eliminated at will and precise thermostatic control for a variety of conditions can be accommodated; even such refinements as a group of heaters around large doorways can be incorporated in such a scheme.

Placing of thermostats is, of course, important as with any heating scheme. Internal air temperature thermostats are usually mounted on walls or building columns approximately 5 ft from the ground and shielded from direct radiation from the heaters. External air temperature thermostats are mounted 5 ft from ground level on the external walls, in weather-proof boxes and away from such influences as steam pipes and non-representative shadows from the building structure falling across them. Thermostats used for the control of a large group of heaters

FIGURE 18.—*Master Control Panel for Ignition, etc., on a Large Radiant Heating Scheme.*
(Courtesy Cammell Laird and Company (Shipbuilders and Engineers), Limited.)

around a doorway could be mounted internally so as to ignite this group of heaters automatically when the cold air enters the shop, or there can be a simple manual over-ride for this function. Again it must be emphasized that money spent on the controls for a heating scheme is seldom wasted, as the saving in fuel costs can be appreciable, besides bestowing the advantages of a completely automatic system.

IV CONCLUSIONS

The value of a planned approach to the building up of some aspects of the industrial load is emphasized by the Authors. Whilst experienced industrial gas engineers have the advantages of a depth of knowledge of the application of gas in industry, it might well be that in many instances there is insufficient knowledge of the industry or processes for which the apparatus or plant is required, with the consequential inability to provide a complete service. This service begins way back in the production line and finishes well beyond the gas-consuming plant.

Work study appreciation and applications, the Authors suggest, contribute more to building of load than overall cost of the gas-consuming plant, or even the price per therm of gas. It is the final analysis of "cost per article processed" that may determine a gain or loss to the load, and every factor affecting the "cost" is vital in the analysis of the problem.

Valuable research work has been undertaken in this country, on the Continent, in the United States of America and elsewhere, and the Authors feel that industry is not reaping the full benefit of this work; further, having designed a piece of gas-burning equipment, it is a matter of variety reduction by standardization that demands that the equipment is used in every field where it can show advantages over other equipment. Does it rest with the gas industry through The Gas Council or Area Boards, or the manufacturers to harness this knowledge, or is it a joint responsibility?

Does the industry develop an excellent piece of equipment, then omit the follow-up of examining every possible advantageous application of that piece of equipment?

The Authors suggest there is much work to be done in the field of process heating, particularly in the continuous or semi-continuous fields, which work could not fail to provide increased loads. They advocate an organized investigation into additional uses of radiant heat, and in so doing appreciate that much knowledge is already in existence, but spread around the Industrial Gas Departments of the various Area Gas Boards. This information might be put to even greater use if it were collated.

The value of automatic programme control in ignition and extinction, *etc.*, of space heaters is stressed on the basis that saving of labour, close temperature control and the psychological satisfaction of "automation" in its simplest form all contribute to reduction in running costs and the greater chance of gaining a load.

Acknowledgments

The Authors would like to express their thanks to the Chairman and Directors of Parkinson Cowan, Limited, for permission to prepare and present this paper, and acknowledge the late Cyril H. Pearson's encouragement.

They would also like to thank the many engineers who pioneered and developed gas-fired radiant heating and its application in this country; Watson House for constant help and advice in matters appertaining to improvements and development; the American Gas Association; Perfection Industries, Ohio; Texas Infra Red Radiant Company, Incorporated; Texas Agricultural Experimental Station; the Schwank Organization, and other industrial organizations and individuals for their ready co-operation in providing information, and to their colleagues of the Industrial Products Division of Parkinson Cowan, Limited, for assistance in preparing the paper.

LITERATURE REFERENCES

[1] Humble Farm Family—Humble Oil and Refining Company, Houston, Texas. March, 1960.

[2] Artificial Curing of Onions. Rosberg D. Texas Agricultural Research Station, Dec., 1959.

[3] *American Gas Association Res. Bull. No. 83*, May, 1960

[4] Extract from Report by Ravich, L. E.

[5, 6, 7] Personal Communications, Perfection Industries, Cleveland, Ohio, 1961.

PRESENTATION, DISCUSSION AND REPLY

Presentation

Mr. F. J. Brewer presented this paper and summarized its contents.

Discussion

Mr. R. F. Hayman (London; Industrial Gas Officer, The Gas Council):—Radiation, one of the three ways by which heat is transferred, has often been a misunderstood subject. Its use in a new technique, remembering black emitter radiant heat processing only seriously dates back to 1942, was hailed with enthusiasm occasionally misplaced, occasionally earning a suspicious reputation based, as we now know, on lack of knowledge and operating experience.

It is inevitable that invidious comparisons have been made between radiative and convective heating, and I beg members not to continue this argument, but to discuss the merits of process heating by radiation where they exist in order that we can see where this technique fits into the pattern of gas in industry, and how we can employ it to increase loads.

The urgent need for increasing production rates of a great number of goods during the Second World War, stimulated the development of newer and faster methods, notably for drying and metal finishing, among them methods using radiation. It was probably inevitable that the ubiquitous electric lamp was first used, and, by 1943, out of some 30 references to the subject 22 described electric lamp units. A classic paper by Andrew and Chamberlain to The Institute of Fuel in 1943 set a standard for the use of gas-heated equipment. Since then, only three papers on this subject have been presented to The Institution of Gas Engineers, all of them short papers, by the Gas Research Board, between 1944 and 1946, clarifying theoretical factors underlying the use of radiation.

It is surprising that it has taken 16 years for the technique to be recorded in detail in the *Transactions* of the Institution, but it says much for the skill of the original investigators that designs laid down in 1942 for black emitter panels and tunnels have remained virtually technically unchanged, with outstanding success, over the intervening years. A prophetic remark in 1944 was made, that gas installations may well supersede the electric plants. I do not think that there is any need to comment at this time on that statement.

From the beginning, two temperature ranges established themselves: medium-temperature black emitter systems operating at temperatures up to 340°C (650°F), occasionally up to 800°F, and high-temperature units not dissimilar to the output of a radiant room heater operating at 800° to 900°C. This in the process field leaves a huge temperature gap, and it is interesting that it has not been found necessary to fill it. Flash drying and curing can be effected in a matter of seconds, but the risk of damage to materials and the technical problems involved usually far outweigh the advantages of high speed. It must be remembered that all systems of rapid drying are designed to eliminate bottle-necks in what is a relatively slow process. Once a bottle-neck in the production line has been eliminated, there is no point in designing for faster speeds other than planning some small reserve.

The Authors have cogent comment to make on this point because the greatest advance since the early days has been not so much in the provision of better equipment, as in the knowledge required to lay out a complete plant in order to give the consumer a heat service. Whatever the production requirements may be, here, as always, background information is required, and it has been left to the Authors to put this on paper, although by now there must be hundreds of installations that can form a basis of valuable operating experience.

The Authors should make no apology for setting out in detail methods to calculate heat requirements for the processing of a variety of objects. Anyone concerned with the development of the industrial load should welcome this information which concentrates on paper a wealth of experience in dealing with consumers' problems. It is easy to suggest that a problem can be solved by the provision of, say, an oven in a corner of a works, but not so easy to give the consumer the full heat service to which he is entitled. The information given in the paper should be supplemented by knowledge already gained by plants in existence, but not enough of this knowledge is published. There are many thousands of gas-heated units now in active use, and yet few recent photographs or reports are available.

The high-temperature radiant heating load is relatively small in the process-heating field, since in many industries even more intense sources of heat are required, but in large-scale space heating there has been a great advance. Superlatives are usually suspect, but the word "biggest" is not yet commonplace for recent intallation. We must not be casual about this important load just because it has come upon us rather quietly. Open spaces now have a way of becoming covered over in industries where working conditions are being improved. Once these spaces are enclosed, they become subject to the Factories Acts and they must be heated for at least some part of the year. A source of energy must, therefore, be made available, and if we do not step in quickly other fuel suppliers will do so. The fact that must be stressed continually is that these projects are just not a miscellaneous collection of appliances, they are fully integrated systems complete with automatic ignition and controls. What better recommendation need there be for the new philosophy that heating installations must be designed, not merely erected. Then, given the right experience and knowledge, the great flexibility of gas will do the rest.

Some members of the gas industry may well regard these installations as a contribution to peak loads, and, therefore, undesirable, but surely we are in business to supply a consumer service that must at times involve peak loads. The maintenance of a heat service may be more complicated than selling an appliance, but it is often more rewarding.

The Authors ask a number of questions and make a number of suggestions. They ask why the gas industry has not been more forthcoming with information to assist in building the process-heating load? They ask whether this country is making the best use of knowledge now being made available on the Continent and in the U.S.A., and, if not, should it rest with the gas industry or the manufacturers to harness this knowledge? They ask whether, having developed an appliance, the gas industry does all it can to follow up possibilities in its application. They suggest that more work on continuous process heating and in automatic control of process lines should be done.

Whether or not agreement is universal with these questions and suggestions, I hope that the forthcoming discussion will ventilate some of them in the sure knowledge that increased understanding of this particular technique for process and space heating cannot fail to be of benefit to those responsible for the increase of the industrial and commercial loads.

Mr. H. P. Barker (London; Chairman, Parkinson Cowan, Limited):—First of all, may I congratulate the Authors on an interesting and comprehensive paper. I have a special reason to know that these two gentlemen have devoted themselves to this subject with unremitting enthusiasm for a number of years; like all enthusiasms, theirs has infected others, and particularly myself.

I should like to make some observations; first, on the whole field of the use of gas in industrial heating.

Despite the effort now being applied, the opportunities for gas in industry are still, in my view, much underrated. It is apparent to all of us who visit factories, that most industrial heat processes are grossly wasteful and that a major contribution can be made to the industrial efficiency of the country by a nationwide overhaul of these processes. This view has a particular force because, in a special sense, most industrial heating processes (and I exclude space heating from this) have a "zero efficiency". By this, I mean that industrial processes involve heating something for some useful purpose and then allowing the object to cool without any recovery of the heat previously absorbed.

It has always seemed to me that gas can do for thermal processes what electricity has already done for motive power processes, but this analogy is imperfect. When electricity is used for a motive power process, it has an inherently self-

adjusting quality, by which I mean that, if the process requires less motive power, the electric motor automatically absorbs less energy. The same self-compensating factors do not exist in thermal processes, from which I deduce that gas engineers should concentrate their minds more than ever upon automatic controls, which will align the combustion of gas to the minimum physical requirements of the task to be performed. This is as true of radiant heating as of anything else.

It pains me, as it obviously does the Authors, to see the number of industrial heat processes operating under manual control and without any effort to introduce time-temperature cycles and things of this kind. I think also that we have somewhat failed to imbue industry with the idea of the automatic flame. Perhaps we should think of a new publicity approach and coin some term such as "thermal automation" in order to convey to industry the spirit of our aims.

Turning to space heating questions, I rather think that the Authors dismiss altogether too lightly the opportunities for outdoor heating. In this field, the selling possibilities seem most attractive. Warm outdoor seating at sporting events and warmed areas for window-shoppers are examples. We have opportunities in this field which our electrical competitors cannot easily exploit. The reason for this is that, speaking broadly, the efficiency of an outdoor radiant heater rises with the absolute temperature of the radiating element. It is easier for such high temperatures to be attained with a flame. The Authors refer to "the only partial success in this country". I believe that there are still some combustion problems to be overcome with these outdoor heaters. I should be interested to know what progress is being made on this.

Lastly, I feel that the enthusiasm of the Authors is well justified, not only by what has been achieved to date in the fields they describe, but also for the prospects that lie ahead.

Mr. L. W. Andrew (London; Director, Watson House Centre, The Gas Council):—I welcome this paper very much indeed, for two general reasons. The first is that we have a paper in which the Authors actually practise what they preach. They ask for more information, and they give us more information. Incidentally, I meet the Authors on various Committees, and this same attitude of mind of theirs appears in British Standard Committees in which we are trying to lay down improved standards for the type of equipment described by them. I thank the Authors for that.

Secondly, they go out of their way to emphasize certain important competitive factors that apply equally to industrial gas, commercial gas and domestic gas. They emphasize the importance of the initial technical service that is given; they emphasize the importance, not of a low initial cost, but of the total cost of a process in relation to the final product. This final product might be a nut and bolt, it might be the taking of a bath, or it might be the process of becoming comfortable. I believe that precisely the same motives apply: the consumer is only interested in getting what he wants at a price which, he knows, is competitive with that of other fuels. To satisfy this requirement, I am sure the Authors will agree, we must have more and more facts on which to base our service, as well as getting information from existing installations.

From the point of view of work on industrial gas at the Watson House Research Station, it seems to us fairly clear that the various processes are so wide and cover such a range that we must pay great attention to the basic principles on which design can be based.

Two examples of our work are relevant to the paper. The first is a fundamental reassessment of radiant heat and convected heat transfer in furnace design. We are going right back to fundamentals to see the conditions under which different proportions of radiant and convected heat will give the best service in relation to the loading of the furnace, temperature, size, and so on.

The second example is the question of drying in its widest sense. The Authors have confined themselves to paint curing rather than to drying. We are doing the same thing on drying and going back to fundamentals on design data for a wide range of drying processes in terms of temperature of products, relative humidity, air temperature and speed. As it comes out, this information will, of course, be made available to everybody.

I am delighted that overhead heating plays such a large part in the paper, because I believe that we have here a very great opportunity. From my point of view, the Watson House Centre deals with overhead heating as a part of space heating. We are involved in testing, approval and installation, and a great number of data have been issued in the last year or two. I hope that the Authors have received them.

Concerning overhead heating, the biggest development in recent years has been in relation to maintenance, ignition and control. We are facing the circumstance that our overhead heaters are getting bigger, and are being installed at greater heights. It will be agreed that this makes it more and more important to consider easy maintenance—or, rather, practically no maintenance—as well as absolute certainty of ignition and absolute certainty of remote control.

The big field lies possibly in outdoor heating—the Authors have suggested this—and the whole question of protection from unusual draughts must be considered.

I should like to ask the Authors, as Mr. Barker has done, whether they have reached the end of the road in designing overhead heaters that are absolutely weatherproof, with foolproof ignition and remote control. The Authors have gone a long way. Have they reached the end of the road?

I am intrigued that the Authors regard products of combustion in a friendly way; it is a refreshing thought. I should like them to remember that the scope for radiant heating by overhead panels goes beyond outdoors and right into indoors. We must look at the whole field, from the complete outdoor to the semi-outdoor and to the indoor heating of factories, which the Authors mention, and also of churches. In all these installations, it is important to remember ventilation and products of combustion.

The biggest immediate field that we have is semi-outdoor heating, where everything is in our favour. The heater is reasonably protected from the elements and, at the same time, the ventilation is such that there are no problems arising from products of combustion.

I must correct Mr. Barker, a privilege that I have never had before. Yesterday, when we discussed how much gas one could get through a ½ in. pipe, I said that it was equivalent to 60 kW. Certainly, it is nearer 60 than 30 kW. I do not know how anybody else can do what we can do in the way of outdoor and semi-outdoor heating.

We do our best to provide information. We can only provide information that we get, on the one hand, and that we get to know about, on the other hand. This paper will stimulate a greater exchange of information between the Area Gas Boards, the research stations and the manufacturers. I welcome it warmly and congratulate the Authors upon it.

Mr. G. E. Thomas (Watford; Area Industrial Gas Engineer, Eastern Gas Board):—I think there are a number of important aspects to this paper. The case histories presented by the Authors are very useful references, for practising and student industrial gas engineers, as to how the complicated process of heat transfer by radiation should best be planned, particularly for process applications, and I should like to thank the Authors for this contribution to the library of knowledge and information on the subject.

The term "infra-red" used by our competitors to stir up public imagination somewhat boomeranged on them and did the gas industry quite a bit of good. "Radiant heat," as I prefer to call it, has certainly proved to be the answer for an ever widening range of applications for drying, curing, heat setting and softening purposes. Knowledge of its capabilities is also growing, but I venture to suggest that there is a great deal we still have to learn regarding the influence of convection, shadow effect, varying weight-to-surface ratio, and colour pigment. The Authors, however, have started something. This is the first paper I can recall in a long time which has attempted to deal seriously with this important subject. I think they have, perhaps, tried to cover the field too fully. I offer this as criticism in the kindest possible way, but I should have liked to see the paper confined much more to process applications rather than incorporating the references to space heating. I think one needs to know a great deal more about the economic and technical factors, which serve to determine the choice between radiant heat and convective heat, and between gas and

electricity. As the Authors rightly say, the industrialist is interested in overall cost per unit of product, in which important contributions are made by savings he is likely to make from decreased capital outlay, decreased floor space, increased speed of heat transfer, and decreased spoilage of product. An exercise along these lines would be rewarding and well worth while.

I recall that, in early 1957, I was asked to provide information for one of the firms whose plant is illustrated in the paper, in connexion with the speeding-up of its paint finishing process. The firm in question was very biased in favour of electricity, for obvious reasons, but when it was shown that gas radiant heat units could provide flux densities per unit area of two to three times that of electrical counterparts, its significant effect on capital costs, space requirements, and speed of drying soon became apparent.

I claim no credit or originality for this. It was no more than any of my colleagues in the industry would have done. I only put it forward as evidence of this important aspect and, also, of the part regularly played by industrial gas engineers in their own "back yards", which ultimately redounds to the mutual benefit of both Area Gas Boards and appliance manufacturers alike.

As regards the effect of heat on colour pigment, some years ago we were confronted with problems associated with the drying of heat-set inks used in printing of relief-stamped letter-headings. It was quickly noticed that different-coloured inks had different rates of drying and setting, and had to be separated into drying lines operating at different speeds. This was all right for single-colour work, but, where multi-colour printing was needed, quite frequently the longer drying period needed for one colour caused greater shrinkage of paper with the consequence that the other colours were frequently out of register. Whilst, in general, radiant heat greatly benefited the speeding-up of production by removing a serious bottle-neck, for multi-colour work the manufacturers were obliged to resort to the slower, but more effective, method of convection drying.

The information given in Section III(c) on possible far-reaching development of radiant heat in the agricultural field, resulting from American research, is particularly interesting to me, representing, as I do, an Area that, apart from its industrial southern and western parts, is predominantly agricultural. A great deal has already been accomplished in the application of radiant heat for poultry brooders, but its application for greenhouses and bulk vegetable stores has not yet been attempted on any measurable scale. Progress in this direction may be limited by the remoteness of town gas mains from many farms and the like, and the relatively high price of town gas compared with other available fuels. We must remember that in the United States natural gas is probably the first consideration. In this country, town gas is probably a bad third. We have also other competitors in the form of liquid petroleum gases: the almost universal application of electricity to farm development is also to be considered a very serious competitor in this field.

I welcome the paper and the expressed desire of the Authors for close co-operation throughout the entire gas industry to develop consumer markets to the fullest extent. The scope for application of radiant heat, whether it be for process applications or space heating, is immense. Industrial gas engineers recognize the value of its tremendous potential; indeed, they do not confine the limits to the range between 650° and 1,500°F. There is a real need for joint effort between Area Gas Boards, research stations, and appliance manufacturers in extending the range considerably to 2,000°F and possibly higher for process heating applications that, at the moment, involve costly and cumbersome furnace structure, and where indirect heating has to be restored to, as opposed to direct. Extending the temperature range of unit radiant heat appliances enables gas to maintain its rightful place as a flexible fuel capable of the fullest application into automated line production.

Mr. H. C. Elles (Liverpool; Technical Sales Manager, Mersey Group, North Western Gas Board):—I should like to congratulate Mr. Brewer and Mr. Ballantyne and to thank them for a paper of great value in that it draws attention to the load-building potential of the various forms of radiant heating panel. I shall confine my comments to the section dealing with space heating of industrial premises, as I feel that it is in this field that the radiant heater has a tremendous value as a load builder, which is not, perhaps, generally recognized.

In the Mersey Group of the North Western Gas Board, not less than 10 per cent of the 25 mill. therms sold to industry in 1960 was consumed by high-temperature radiant space heaters. One notable installation consumed 340,000 therms. This gives some indication of the present value of the industrial space heating load. The potential value is also recognized, and no factory is built in the group area without an attempt being made at an early stage to convince its planners that gas can heat the building efficiently and economically, where this is true. The main advantage claimed, in addition to those referred to by the Authors, is the much lower capital cost. The total cost of a gas-fired radiant heating installation with electric ignition, and temperature control, can frequently be only 50 per cent of the cost of a conventional heating system incorporating a boiler. The flexibility and controllability of such a system can also make possible lower running costs than with other systems.

The space heating by gas of factory premises can also give further opportunities to increase the gas load for process heat. Too frequently, gas is not accepted because low-grade process heat is supplied from the central boiler plant, required in any case for space heating. Remove the main function of the boiler plant, and a case may easily be prepared for the total elimination of this expensive item, which would result in a greater opportunity for gas sales.

To refer to the opening paragraphs of Section III(D), having had some experience in the planning and installation of some industrial radiant heating systems, I agree wholeheartedly that there is a lack of information on the correct method of approach in the design of this type of installation. With this in mind, a good deal of information has been gathered from one particularly large installation at a shipyard in Birkenhead, for which the Authors were responsible, by the use of recording instruments for air temperature and relative humidity both inside and outside, the measurement of total radiation at intervals over a representative section of the floor, estimation of the actual ventilation rate and recording of the instantaneous gas rate of the system.

Brief details of the building are as follows: floor area, 500,000 ft²; average roof height, 55 ft; calculated heat losses, 36 mill. Btu/h. The installation comprises 500 (six-unit) Schwank-type heaters, with electric ignition and thermostatic control.

Experience gained from this installation has convinced me of the following: (i) That angle mounting of heaters is to be preferred to high-level horizontal mounting, wherever this is possible; (ii) that thermostatic control is to be recommended for economy's sake, despite other considerations mentioned in the paper; (iii) that heating to comfort level of relatively small areas during overtime working is perfectly possible with great economy; (iv) that actual ventilation rates can vary considerably from the most careful theoretical estimates.

Finally, I join the Authors in their appeal for the collation of the mass of information on this subject that must exist among industrial engineers. I recommend that this is a matter worthy of the attention of Watson House or the Gas Council's Industrial Gas Development Committee, which have already done so much excellent work of a similar nature.

Mr. L. T. Minchin (London):—I think I detect a "heresy" at the end of Section III(A) of the paper, where the Authors say, if I understand them correctly, that there is no loss of heat energy within the visible spectrum if one has a low temperature of 650°F. I do not know whether I am correct in thinking this implies that energy in the form of light is wasted. However, the fact that one's eyes can see radiation of a certain wavelength does not make it any less effective as a heating element. The chief reason for choosing either a high-temperature or a low-temperature radiator is that one gets a greater concentration of output with the higher-temperature source, which is often a very important matter in process heating.

On the question of space heating, I am glad that the Authors put space heating in inverted commas. I hate the term, but I

do not know a suitable alternative. The remarks of the Authors on methods of calculating radiation space heating requirements underline the ignorance of all of us on this matter; I do not think the Authors will be offended by this. They suggest that one should work out the heat loss by the conventional method using the conductivity of the walls and windows and so on, although they know that the air temperature is not what one is aiming at. I suppose that what one has to do is to take Figure 15 and find out what air temperature one will get by their conventional calculation. If it does not agree with the amount of radiant heat that one is getting, one oscillates up and down the curve until one finds the right point.

Figure 15 is also of great interest to me, and I should be glad if the Authors would divulge where they got it from, or whether it is based on their own personal observations. It provides the kind of data that are badly needed in the radiant heating field, and which seem to have been conspicuously absent from the literature so far.

If one makes a test in a building that has this kind of heating, it is most difficult to forecast whether, in the depth of winter, it will be quite satisfactory. With the conventional warm-air type of heating, because one knows the difference between the inside and outside temperatures, all that one has to do is to add this on to the lowest outside temperature that one would be likely to experience and one knows the minimum inside temperature. But it is not the same with radiant heating, because one has the additional factor of the radiant energy actually streaming on to one's skin; so one cannot apply the same simple arithmetical addition as one can with ordinary heating.

Watson House is always being invoked to help in these matters. I invoke Watson House again, please to provide data on what is "comfort", how one can achieve it and what amount of radiant and convected heat one needs for it.

Mr. W. H. Tarn (Cardiff; Industrial Gas Engineer, Wales Gas Board):—I welcome the opportunity of saying a few words on this interesting paper. In the Introduction, a question is asked that can easily be answered. Up to the present, industrial engineers have primarily been concerned wholly with utilization of heat. We have entered a most competitive era in industrial engineering, and industrial engineers today have to take in the whole pattern of production. The Authors give full emphasis to the fact that any heat-consuming plant has to be designed to follow the pattern of a production line.

I believe that it is the enthusiasm of the Authors that has enabled infra-red heating—or, as I prefer to call it, radiant heat—to be developed as far as it has been. There is no doubt that anybody who has been in co-operation with the Authors at any time will realize their enthusiasm.

I was particularly interested in the list of agricultural drying installations. I believe that the gas industry has to do far more market research into these applications. Over the years, we have all done little jobs here and there that have culminated ultimately in quite big installations. In order to develop this type of load, each industry and each process in an industry has to be examined very carefully.

I add my congratulations to the Authors on an interesting paper.

Written Reply

The **Authors**, in reply, wrote:—It is clear from the discussion that interest in the building up of industrial loads is such that much more work remains to be done in the collation and documentation of information.

Mr. Hayman rightly emphasizes that radiation has often been a misunderstood subject; in the Authors' experience, not only misunderstood, but neglected. The emphasis made by Mr. Hayman that projects are not just a miscellaneous collection of appliances, but fully integrated systems complete with automatic ignition and control, brings more forcibly forward the Authors' contention that one must not consider in isolation the gas-consuming plant, but co-ordinate fuel, plant and layout. There is also a growing awareness that space heating loads, although these may sometimes come at times of peak load, are essential in maintaining a healthy growth characteristic. The Authors are in complete agreement with Mr. Hayman on these points.

Mr. Barker speaks of the fact that most industrial heat processes have a "zero efficiency". Although this may be true in the sense of thermal efficiency, there are two main points that follow. Firstly, would it be economic to attempt to recover low-grade heat from processed objects or flue gases; secondly, the consumer is not primarily concerned with thermal efficiency for its own sake, but in the cost in terms of money and time of the processing of his goods and in the technical advisory service that the industry can offer him.

With regard to outdoor space heating, mentioned also by other contributors, the Authors' experience, in this country, and that of Continental and American friends, leads them to proceed with caution. The apparatus mentioned in literature reference 7 is now under test in this country, and, if successful, may give an answer to some of the problems that now beset the industry.

The Authors would like to draw particular attention to the splendid phrase "Thermal automation", which expresses to them, in a fresh and modern way, the industry's way of making the best use of its fuel.

Mr. Andrew, referring to the need for examination of radiation and convection heat transfer and the need to go back to fundamentals, makes it clear that one must consider the source of heat, whether it be radiation or convection, or a combination of the two, and, although the paper deals more specifically with radiation, use is in fact made of the combination of these two methods and not purely radiation. A strong case is made for superimposing radiant heat on to existing convection processes, thereby speeding up the process.

With regard to his reference to difficulties encountered with overhead space heating, due to the tendency for these heaters to be fixed higher and higher the Authors would say, as a result of more recent experience, that the tendency now is to have the heaters mounted lower and at an angle on the side walls of the building and from stanchions or crane rails, thus facilitating maintenance; a more important point is that the heaters are much nearer the point of application. One also gets a very good spread of heat across the building and, as can be seen in the paper, it is possible to get a very nearly uniform spread of radiation across the 100 ft width of shop by having heaters on opposite walls.

Mr. Andrew asks whether the Authors are at the "end of the road" in outdoor heating. Having previously said that we would wish to proceed with caution, the Authors would reply to Mr. Andrew by saying that, subject to overcoming some of the problems that now beset them, they will be at the beginning of the road and certainly not at its end.

Mr. Thomas, referring to the industrialist's interest in overall cost per unit of product, reinforces the Authors' contention that capital cost and running cost do not of necessity determine the cost per unit of product. Once again, the Authors stress that it is a combination of plant, fuel, layout and work study considerations that will determine the industrialist's main interest, the final cost per unit of product.

On the question of the effect of shadowing, colours and the like, the Authors would point out that, as mentioned in the paper, it is essential to establish by actual test in each case the process time for design purposes, which automatically takes into account the factors outlined by Mr. Thomas.

Ink drying is a very difficult matter because there is a much bigger difference in absorption properties of inks than of paints, and it is further complicated by the contraction of the paper, which always contains a certain amount of moisture. It is not so easy to obtain from ink manufacturers modified fluids suitable for drying by rapid methods. It is, therefore, as in other cases, necessary, before recommending plant and layout, to undertake tests, after which one can recommend the desirablity of using radiant or convected heat.

Mr. H. C. Elles, referring to the value of radiant heaters in industry, brings into the discussion valuable information drawn on as a result of co-operative effort between himself and the Authors in the provision of what was and probably still is the largest gas-fired radiant heating scheme in the world installed at a shipyard in Birkenhead.

In stressing the fact that the total cost of a gas-fired radiant heating installation with all its controls can frequently be as low as 50 per cent of the cost of a more conventional heating scheme incorporating boilers, he brings home the fact that boiler costs can be very heavy, and, if it is unnecessary to instal a boiler, additional gas loads may well be obtained for process heat.

The Authors find themselves in disagreement with Mr. Minchin when he infers a lack of information on comfort conditions and what radiant and convected heat is required to achieve it. There are, of course, available many valuable statistical data and the written word of such experts as R. W. Shoemaker and Dr. T. Bedford. Both these Authors have covered the subject of comfort and equivalent temperature conditions adequately. Comfort conditions are, of course, a personal assessment, and it is impossible to provide within one room or building conditions to suit all persons. The broad band shown on Figure 15 indicates the general limits of comfort. The mean-radiant-temperature method is an accepted scientific method of assessing the amount of radiant heat required for comfort conditions. In general, much valuable work has been done by A. F. Dufton, F. R. L. White and H. H. Bruce in this country.

Referring to Figure 15, the Authors can only say that, whilst it is of great interest to Mr. Minchin, this has been built up as a result of their personal experience in the field and partly based on information put at their disposal.

The Authors think that the apparent heresy detected by Mr. Minchin might well have been better explained if they had enlarged on the subject. High-temperature sources of the order of 1,500°F would emit radiation of wavelength of peak emission intensity of about 2·5μ, or perhaps half of that of the panel radiating at 650°F. The essential difference, of course, between high- and medium-temperature sources of radiant heat lies in that part that can be put to significant use. The percentage of heat energy given off within the visible spectrum is of low order by comparison with the total energy emitted. It is a fact that energy of this wavelength is not readily absorbed by materials generally considered in this paper.

Mr. Tarn, referring to the gas industry having entered a most competitive era, agrees with the Authors that one has to take in the whole pattern of production, but they are sure Mr. Tarn will forgive the suggestion that the heat-consuming plant does not necessarily have to be designed to follow the pattern of an existing production line. If, with applied work study and method study considerations, the industry is able to persuade the industrialist that it is to his advantage to alter the production line, then the value of work study is truly appreciated.

Mr. Tarn has accepted the challenge in the provoking list of possible agricultural drying applications, and the Authors agree that far more market research and design research into these and other applications is desirable. If such work could be undertaken, it might well be that the industry could find fresh and green fields for the sale of "industrial gas".

The Authors could hardly hope for better reward than the quality and enthusiasm of the discussion, other than perhaps the plea that the industry might feel it profitable to investigate other possible applications of industrial gas within the scope of the paper presented.

THE THERMODYNAMIC STUDY OF THE REFORMING OF HYDROCARBONS AND ITS APPLICATION TO AUTOTHERMIC GENERATORS

By J. RIBESSE (Engineer) and C. VAN MAELE (Engineer), Distrigaz, S.A., Belgium

COMMUNICATION No. 580

TABLE OF CONTENTS

		PAGE
I	Summary	631
II	Introduction	632
III	Determination of the Thermodynamic Equilibrium of Reforming Reactions	
	(1) Defining the Problem	632
	(2) Basis of Calculations	632
	(3) Relations Between Variables	632
	(4) Example of Calculation	633
	(5) Determination of the Equilibrium Temperature	633
	(6) Determination of the Characteristics of the Reaction Products	634
	(7) Conclusions	634
IV	Industrial Achievements in the Realization of Autothermic Catalytic Reforming Generators	636
	(1) Operating Results of Some Autothermic Reforming Plants	636
	(2) Autothermic Generators Applied to the Gas Industry	636
	(3) Example of Cost Price of Gas Reconstituted at 4,250 cal/cu.m Obtained by Treating Butane in an Autothermic Generator	637
	(4) New Technique in Autothermic Catalytic Reforming	637
	APPENDIX	
	Calculation Notes	638
	Presentation, Discussion and Reply	639

I SUMMARY

The reforming of hydrocarbons is a reaction where partial oxidation of the hydrocarbon molecules by oxygen, steam or carbon dioxide takes place, giving gaseous products consisting mainly of hydrogen and carbon monoxide. These two gases are basic products of many industrial processes, such as the synthesis of ammonia, and, principally, the production of town gas.

In the first part of this study are established the thermodynamic equilibrium conditions for the mixture of hydrocarbon, oxygen and steam, in order to know the theoretical composition of the reformed gas and the reaction temperature in an autothermic system, i.e., needing no outside heat.

Experimental results and industrial operational data have been shown to be very near the calculated theoretical values, this being achieved by the use of highly active catalysts.

The graphs obtained from the results of these calculations have enabled the Authors to define the appropriate scope of industrial generators.

In the second part are given a few industrial operating results of autothermic generators, principally in the field of peak-load town gas production.

Autothermic processes are an adequate answer to the problem created by peak-load demands, by their great flexibility of operation, very high thermal efficiency, and small capital cost through simplicity of installation.

A new autothermic process has just been tested. Its main features are thermal efficiency very near 100 per cent and a gaseous product containing more hydrogen, thus improving the latter's interchangeability with traditional town gas for use by the Gas Industry.

II INTRODUCTION

In recent years, larger and larger quantities of hydrocarbons have become available on the market, for example, natural gas, refinery tail gases, firedamp, liquid petroleum gas, light distillates, and various oils.

Many industries have concentrated their efforts on the utilization of these new basic products, and in particular the chemical industry and the Gas Industry.

One of the principal utilization techniques is the catalytic reforming process, which consists of partial oxidation of the hydrocarbon by oxygen (air), steam or carbon dioxide, in presence of an appropriate catalyst, with the following reactions:—

$$CnHm + \frac{n}{2}O_2 \rightarrow nCO + \frac{m}{2}H_2 \quad . \quad . \quad . \quad (1)$$

$$CnHm + nH_2O \rightarrow nCO + \left(\frac{m}{2} + n\right)H_2 \quad . \quad (2)$$

$$CnHm + nCO_2 \rightarrow 2nCO + \frac{m}{2}H_2 \quad . \quad . \quad . \quad (3)$$

The products obtained from these reactions are principally composed of hydrogen, carbon monoxide and small quantities of carbon dioxide, methane, water vapour and nitrogen. These products are suitable for many utilizations, such as the production of town gas, synthesis of ammonia, synthesis of urea, reduction of iron ore, *etc.*

Through physical chemistry, the possible evolutions of a reaction are known more or less accurately, and one can then determine the optimum working conditions.

In the next section is developed a method of calculating the theoretical equilibrium conditions of reforming reactions.

III DETERMINATION OF THE THERMODYNAMIC EQUILIBRIUM OF REFORMING REACTIONS

(1) Defining the Problem

Let us consider a mixture composed of hydrocarbon, oxygen (air) and steam or carbon dioxide under a determined pressure. These elements react together to give a gas composed of carbon dioxide, carbon monoxide, hydrogen, methane, nitrogen and water vapour.

In this problem, it is necessary

(*a*) to determine the reaction conditions, *e.g.*, the proportions of the constituents of the produced gas, the temperature of reaction, thermal efficiency, *etc.*;

(*b*) after a systematic theoretical study of the different mixtures possible, to determine the optimum conditions that have to be realized in order to obtain desired conditions in the gas produced (such as high percentage of hydrogen, small percentage of residuary methane, maximum efficiency, calorific values, *etc.*)

(2) Basis of Calculations

(*a*) Concentration of the reaction products follow the next equilibrium equations for which the equilibrium constants are known:—

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad K_1(T) = \frac{pCO \times pH_2O}{pCO_2 \times pH_2}$$

$$CO + 3H_2 \rightleftharpoons CH_4 + H_2O \qquad \frac{K_2(T)}{p^2} = \frac{pCO \times p^3H_2}{pCH_4 \times pH_2O}$$

$$C + CO_2 \rightleftharpoons 2CO \qquad \frac{K_3(T)}{P} = \frac{p^2CO}{pCO_2}$$

$$C + 2H_2 \rightleftharpoons CH_4 \qquad P \times K_4(T) = \frac{pCH_4}{p^2H_2}$$

with $$K_4 = \frac{K_2}{K_2 \times K_1}$$

In these equations, T is the absolute temperature, p the partial pressure, and P the absolute pressure.

(*b*) At the state of equilibrium, oxygen is no more present.

(*c*) At the state of equilibrium, CH_4 only is left as hydrocarbon: this hypothesis is acceptable, as at the considered temperature (600° to 1,000° C) the energy of formation of CH_4 is much lower than that of its higher homologues.

(*d*) Only CO_2, CO, H_2, CH_4, N_2, H_2O and C (free carbon) can be found in the reaction products.

(3) Relations Between Variables

The conditions to be fulfilled by the reactions are as follows:—

(*a*) *Balance of Matter*

The sum of atoms of a particular element stays identical for the reactants and reaction products.

(*b*) *Thermodynamic Equilibrium*

The products will be found in quantities in accordance with the equilibrium constants.

(*c*) *Balance of Power*

The total energy of the reaction products and of the calorific losses has to equal the energy of the reactants plus the calorific energy from the outside.

$$\underbrace{\Sigma C + \Sigma O + \Sigma H_2 + \Sigma N_2}_{\text{before reaction}} = \Big\{ a + \Big(\overbrace{\frac{\Sigma O}{E}}^{A} - 2a - i\Big) + \Big(\overbrace{\frac{\Sigma H_2 - 2\Sigma C + 2\Sigma O}{E}}^{B} - 2a - 3i + 2f\Big) + \Big(\overbrace{\frac{\Sigma C - \Sigma O}{E}}^{C} + a + i - f\Big) + \frac{\Sigma N^2}{E} + i + f \Big\} E \quad . \quad (1)$$

after reaction

in which:

ΣC is the sum of atoms of carbon in the mixture at the entrance of the reactor, corresponding to 1 molecule of hydrocarbon;

ΣO is the sum of atoms of oxygen in the mixture;

ΣH_2 is the sum of molecules of hydrogen in the mixture;

ΣN_2 is the sum of molecules of nitrogen in the mixture;

a = quantity of CO_2 in the products;

i = quantity of H_2O in the products;

f = quantity of free carbon in the products;

A = quantity of CO in the products;

B = quantity of H_2 in the products;

C = quantity of CH_4 in the products;

E = number of molecules of gas produced by 1 molecule of hydrocarbon.

It can be so controlled that condition (*a*) is fulfilled. Condition (*b*) can be expressed by:

$$\frac{A.i}{a.B} = K_1(T) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$\frac{A.B^3}{C.i} = \frac{K_2(T)}{P^2} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\frac{A^3}{a} = \frac{K_3(T)}{P} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Finally, condition (*c*) requires equality between the energy introduced with the molecule of hydrocarbon and the energy given out by the products of reaction.

$$Qlo + Qso + Co = Ql + Qs + R \quad . \quad . \quad . \quad . \quad . \quad (5)$$

In this equation

Qlo and Ql = Potential heat of the reactants and products of reaction.

Qso and Qs = Sensible heat.

R = Losses by radiation and convection of the reactor = $f(T)$.

Co = Outside supply of heat.

In order to know the equilibrium conditions, five equations have to be solved (1), (2), (3), (4), (5).

The known terms of these equations are: ΣC, ΣO, ΣH_2, ΣN_2 (quantities introduced in the reactor), So and P.

The unknown variables are a, i, f, E, T, to make five unknown terms. (A, B, C, are known functions of the other terms.)

It is thus possible to resolve this problem. A difficulty arises though from the fact that the five equations are non-linear functions.

A semi-graphic method of resolving the problem will be stated, giving an image of the influence of the different variable factors (composition of the mixture before reaction, outside supply of calories, pressure) on the composition of the reaction products, equilibrium temperature, efficiency, *etc.*

(*Note:* Free carbon is not always present in the reaction products; calculations can give negative values for f; in such cases, equation $2CO = CO_2 + C$ has no more meaning, since there is no free carbon; we can then suppose $f \equiv o$ and cross out equation (4); there are then four equations (1), (2), (3), (5) and four unknown factors a, i, E, T. The two systems of equations with $f \neq o$ and $f \equiv o$ do not give the same results except in the case where $f = o$; the first system will be adopted when $f > o$ and the second when $f < O$.)

(4) Example of Calculation

Let us take a mixture of CH_4/air/H_2O at atmospheric pressure and determine the conditions of equilibrium when the preheating temperature of the mixture is varied:

$CH_4 = 1$; $O_2 = 0{\cdot}54$; $N_2 = 2{\cdot}06$; $H_2O = 0{\cdot}25$; $P = 1$ atm.

(*a*) We shall choose different temperatures within the probable area of the reaction, thus: 630°, 660°, 700°, 750° C.

(*b*) for each of these temperatures for which are known the values of the constants of equilibrium, we calculate with equations (1), (2), (3), (4) the characteristics of the reaction products.

If we find negative values for $f (f \leqslant o)$, we must eliminate equation (4) and consider $f \equiv o$. We shall find the same results in the two systems, if $f = o$. (See details of calculations in the Appendix to this Paper.)

(*c*) the results of calculations in both hypothesis $f \neq o$ and $f \equiv o$, are given in Table 1.

$R = 2{\cdot}6$ (air/CH_4); $V = 0{\cdot}25$ (steam/CH_4)

In Table 1,

Ql = Potential heat of the products at 0° C and 760 mm Hg.

Qs = Sensible heat of the products = $E \int_0^T Cp \, . \, dT$.

Qo = Total heat of reactants.

ΔQso = Supplement of energy from the preheating of the products from 38° C to T preheating.

(5) Determination of the Equilibrium Temperature

On a graph (Figure 1) with the abscissa graduated for enthalpy and the ordinate for temperature (° C), we trace:

(*a*) The two curves $Ql = f(T)$, of which the values are determined in the two cases: $f \neq o$ and $f \equiv o$. (See Table 1.)

These two curves cross one another at a point A, where the two systems of equations give the same results $f = o$ and correspond to the theoretical limit of free carbon formation.

(*b*) At the point $Qo = 9{,}688$ cal (enthalpy of the mixture) a vertical line.

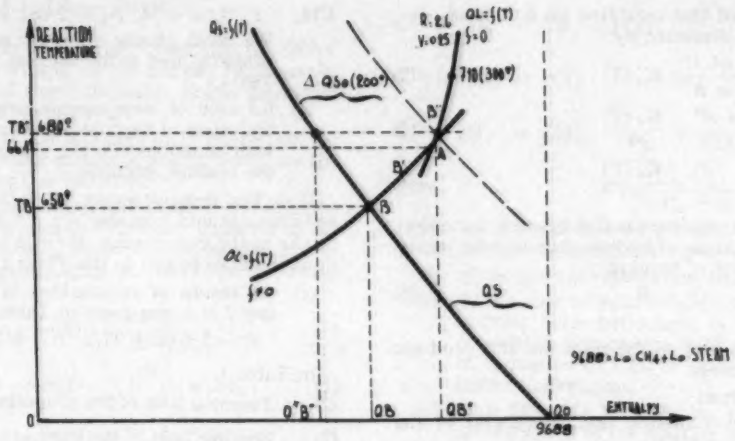
(*c*) From the point Qo, the curve $Qs = f(T)$—(See Table 2)—so that the values of Qs are measured from the vertical line $Q = 9{,}688$ towards the temperature axis.

At the point B of intersection of the two curves Ql and Qs is found the state of equilibrium of the reaction, for at point B we find $Qlo + Qso = Qo = Ql + Qs + R$; and, if the losses R are neglected, we have $Qo = 9{,}688$ and $Ql + Qs = 9{,}688$, for a value of $T = TB = 650°$ C.

(*d*) Congruent curves to $Qs = f(T)$ and at a distance from the latter (towards the higher values of Q), of values calculated Qso (see Table 1); these curves cross the curve $Ql = f(T)$ at points B′, B″, B‴ *etc.*, for the calculated values of the preheating heats of the reactants.

Table 1

	$f \equiv o$				$f \neq o$								
T	810°	750°	700°	660°	660°	630°	$T°$ Mixture	38°	100°	200°	300°	400°	500°
CO_2	1·96	2·4	3	3·9	3·9	5·2							
CO	16·8	16·2	15·1	13·4	13	9	Qo	9,688	9,772	9,917	10,068	10,223	10,390
H_2	37·9	37·5	36·3	34·1	34·3	31·9							
CH_4	0·09	0.4	1·2	2·5	2·4	3·2							
N_2	38·8	39·1	39·7	40·7	40·8	42·5	ΔQso	0	84	229	380	535	701
H_2O	4·4	4·4	4·7	5·3	5·6	8·1							
E	5·3	5·26	5·18	5·05	5·04	4·84							
f	0	0	0	0	+ 0·5	+ 3·2							
Ql	8,986	8,940	8,835	8,677	8,662	8,402							
Qs		1,308		1,125	1,125	1,041							



Reaction CH_4 + 2·6 Air + 0·25 H_2O

FIGURE 1.—*Determination of the Equilibrium Conditions.*

Points B′, B″, *etc.*, determine the reaction conditions of equilibrium for preheatings the reactants at 100°, 200° ... °C.

For

$$Ql = QB'' \qquad Qs = 9{,}688 - Q^{o}B''$$
$$Qlo = 9{,}688 \qquad Qso = QB'' - Q^{o}B''$$

and

$$Ql + Qs = Qlo + Qso.$$

These two sums, being equal, show that the equilibrium of energy is reached at temperatures T_B, T_B, ... for preheatings of the reactants to 100°, 200° ... °C.

(6) Determination of the Characteristics of the Reaction Products

The reaction temperatures of equilibrium are now known; it is easy to ascertain other thermodynamic characteristics, by interpolating between the values found at the temperatures chosen for the calculations (Table 1).

This is how the data in Table 2 were established.

TABLE 2.—*Reforming of* CH_4: $R = 2{\cdot}6$, $V = 0{\cdot}25$, $P = 1$ atmosphere.

Preheating T° (°C)	38°	100°	200°	300°	400°	500°
Reaction T° (°C)	650°	660°	680°	710°	745°	800°
CO_2	4·3	3·9	3·4	2·8	2·4	2
CO	12	13	14·4	15·3	15·3 v	16·8
H_2	33·6	34·3	35·5	36·6	37·4	37·8
CH_4	2·6	2·4	1·7	1	0·5	0·1
N_2	41·2	40·8	40·1	39·6	39·1	38·9
H_2O	6·2	5·6	5	4·6	4·4	4·4
f	1·4	0·56	0	0	0	0
Expansion ..	4·98	5·04	5·13	5·2	5·26	5·3
Thermal Efficiency	0·856	0·881	0·91	0·916	0·926	0·93

The temperature of 38° C given in the first column corresponds to the temperature of saturation of the mixture studied for $P = 1$ atmosphere.

The thermal efficiency equals the PCS (gross calorific value) of the final gas multiplied by the expansion and divided by the PCS of the CH^4.

(7) Conclusions

We have thus found the characteristics of the reaction for a determined mixture; we can in the same way trace other diagrams $Ql = f(T)$ corresponding to other possible values of mixture for the reactants. For example, $V = cst$ and R variable or $R = cst$ and V variable.

We thus obtain families of curves and results enabling us to explore completely the possibilities offered by the reaction of methane with air and steam (Figure 2).

It will be noted that:

(*a*) Any increase in the temperature of reactants (R and $V = est$) leads to an increase in the temperature of reaction and a decrease in the residual CH^4.

(*b*) The bottom right-hand area of the diagram, limited by the dotted curve, corresponds with conditions that create formation of free carbon, which militates against the efficiency of the reactor.

The limits of carbon black formation are pushed back by an increase of steam. The reaction temperature is lowered and the efficiency is generally increased.

(*c*) the calorific efficiency is lowered by an increase in the ratio Air/$CH^4 = R$, as this increases the temperature of reaction.

(*d*) It is thus seen that the working zone is limited:

(i) towards lower temperatures by the curve $T° = 0$,

(ii) towards the south-east, by the "border" curves of free carbon formation,

(iii) towards the north-east by the calorific value of the process.

Similar families of curves have been traced for the theoretical study of the reforming of other hydrocarbons, such as propane, butane, light distillates, with air, oxygen and steam at atmospheric or other pressures.

The study of these charts has not only guided us in choosing the values giving the best results in working autothermic generators, but has also enabled us to predict the changes in performances when a modification is brought to the plant (for example, better recuperation of the sensible heat, or working under high pressure).

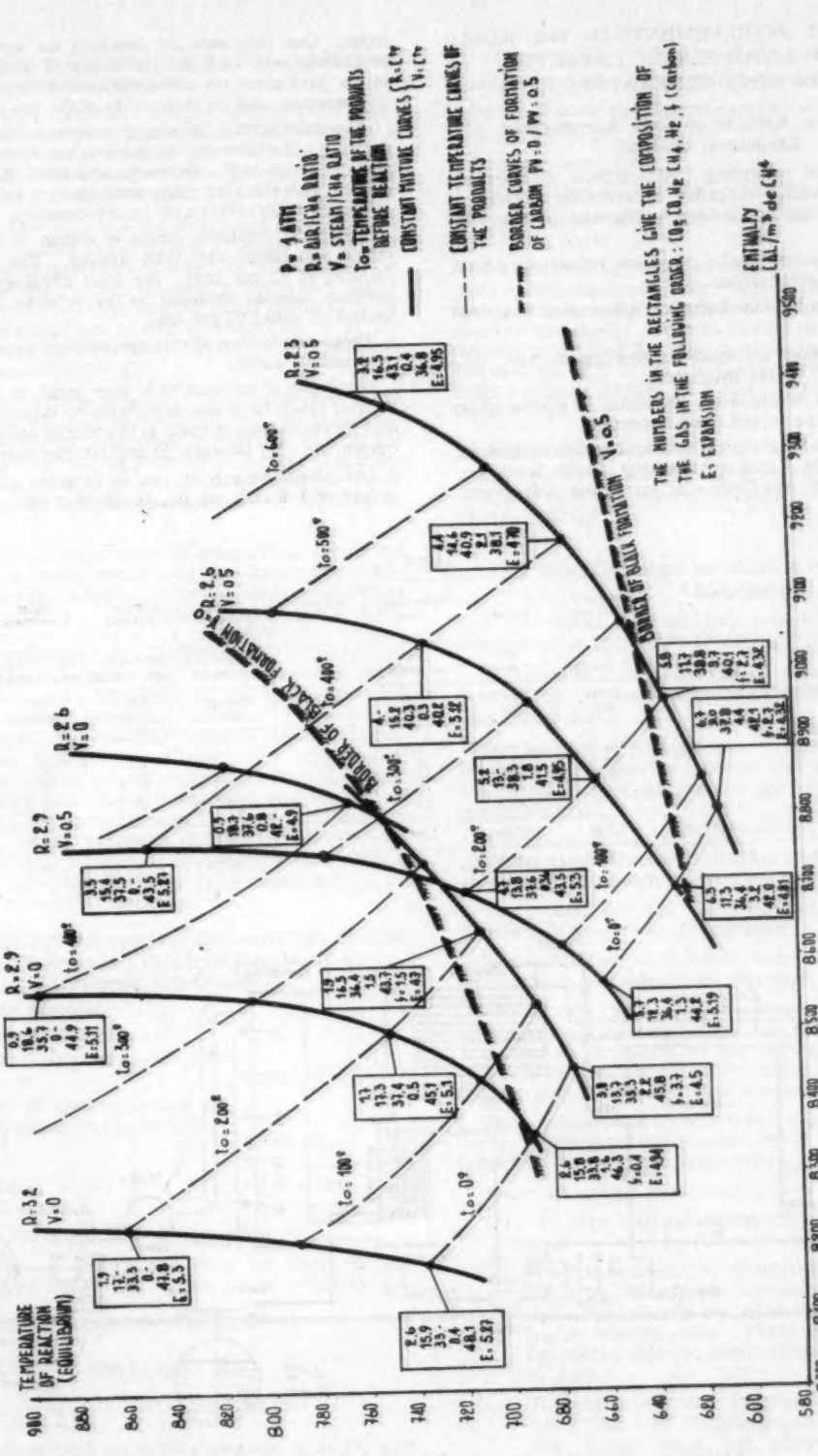

P = 1 ATM
R = AIR/CH4 RATIO
V = STEAM/CH4 RATIO
to = TEMPERATURE OF THE PRODUCTS BEFORE REACTION
CONSTANT MIXTURE CURVES (R = Cte V = Cte)
CONSTANT TEMPERATURE CURVES OF THE PRODUCTS
BORDER CURVES OF FORMATION OF CARBON PH2O / PH2 = 0.5
THE NUMBERS IN THE RECTANGLES GIVE THE COMPOSITION OF THE GAS IN THE FOLLOWING ORDER : (O2, CO, H2, CH4, N2, % (carbon) E: EXPANSION
BORDER OF SOLID FORMATION V=0.5
TEMPERATURE OF REACTION (EQUILIBRIUM)
ENTHALPY (kJ/m³ de CH4)

FIGURE 2.—*Thermodynamic Equilibrium of the Reaction CH_4/Air/Steam.*

IV INDUSTRIAL ACHIEVEMENTS IN THE REALIZATION OF AUTOTHERMIC CATALYTIC REFORMING GENERATORS

(1) Operating Results of Some Autothermic Reforming Plants

The technique of reforming hydrocarbons with oxygen (air) and steam, which is called autothermic because it needs no outside heating, is very widespread in many industries.

Table 3 shows some results of a few reforming plants, treating different hydrocarbons.

Its application to the Gas Industry, is discussed in greater detail.

(2) Autothermic Generators Applied to the Gas Industry

Since the Second World War, variations in consumption of gas have become more and more important.

The ratio between maximum winter and minimum summer consumption exceeds 3 and is increasing rapidly from year to year. There are, moreover, the increasing daily variations. One thus sees the necessity for arranging means of producing peak-load gas, the choice of which must be based in the first place on economic considerations, on flexibility of operation, and on the quality of the gas produced.

The autothermic reforming technique fulfills these points perfectly; the economy of this process derives its low capital cost from its high efficiency, and from the low operating costs. This cracking plant costs about 1 mill. Belgian francs (about £7,000)/1,000 cu.m. hourly capacity.

The plant produces steam in excess of its own requirements and needs very little upkeep. The efficiency of reforming is 92 per cent; the total efficiency (*i.e.*, the ratio between calories rendered to the network and calories absorbed) is about 97 per cent.

These production plants are entirely automatic and need no constant watch.

Flexibility of production is very great, as a generator can be shut down for a few days, with no intervention necessary, and its starting-up process is practically instantaneous. The output can vary between 20 and 100 per cent of the normal.

The plants already in use in Belgium give a total daily output of 1·8 mill. cu. m., about 68·2 mill. cu. ft.

Table 3

Nature of Hydrocarbon ..	Firedamp 7,500 cal.	Butane	Coke Oven Gas	Refinery Tail Gas	Light Distillates 0·1% S	Synthesis Restgas	Light Distillates
Oxydizing Nature	air + steam	air + steam	air + steam	air + steam	air + steam	air + oxygen + steam	air + oxygen + steam
Utilization gas	Town gas	Town gas	Town gas	Town gas	Heating gas	NH3 synthesis	NH3 synthesis
Cracked gas							
CO_2	4·5	5	3·5	5·9	5·5	5·7	7
CO	14·5	17·5	13	16·3	18	20·7	24·5
H_2	38·5	36	45	39	28·5	45·8	45·4
CH_4	1	1	1·5	0·8	1·5	0·4	0·4
N_2	41·5	40·5	37	38	46·5	27·4	22·5
Upper Calorific Value (cal.)	1,700	1,720	1,900	1,760	1,560	2,063	2,170
Density (air = 1)	0·64	0·67	0·58	0·65	0·73	0·58	0·60

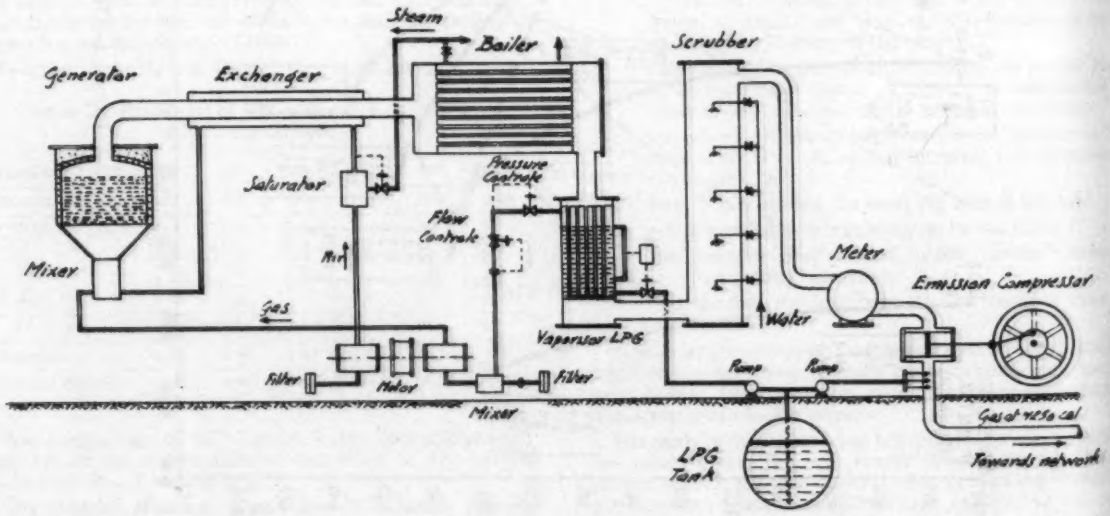


FIGURE 3.—*Flow Diagram of a Peak-load Gas Production Plant.*

Figure 3 shows a typical peak-load gas plant working on the autothermic reforming principle.

The gas, steam and preheated air, are automatically regulated to give constant proportions, and then mixed in a special mixer at the base of the generator. The latter, which consists of a steel cylinder lined on the inside with refractory materials, contains the nickel catalyst.

The reaction takes place at a temperature of about 800° C. The reformed gas leaves the generator at about 750° C and exchanges part of its sensible heat with the air and steam for the reaction; it then passes through a waste-heat boiler giving steam for the reaction and for other services in the Works. The reformed gas is still at about 200° C at the outlet of the boiler; it then goes through an L.P.G. vaporizer, to pass out at less than 100° C.

It finally enters at the base of a cooler-scrubber. The exact proportions between hydrocarbon, air and steam are effected by the use of volumetric blowers driven by the same motor and with the help of an automatic regulating system that corrects the proportions of the different fluids to meet the correct temperature required in the catalyst bed.

The Storage of L.P.G. is done in spherical or cylindrical tanks. The more recent installations have their tanks underground, a solution that is more economical, takes up minimum space and provides a higher safety factor. The liquid petroleum gases are pumped to the utilization points: vaporizers and spray injectors. In general, liquid petroleum gases free of organic sulphur are reserved for reforming; the cruder L.P.G. used for enriching gas to the required calorific value may contain organic sulphur. The enriching fraction is generally incorporated, through liquid injectors, directly into the delivery line of the outlet compressors. This very simple solution ensures at the same time the cooling of the compressed gas. Special automatic systems control the flow of L.P.G. in proportion to the output of reformed gas. In some cases, vaporized L.P.G. is incorporated separately in the final mixer of the production plant; this is then regulated automatically by a valve controlled by an instantaneous-response Wobbemeter.

(3) Example of Cost Price of Gas Reconstituted at 4,250 cal/cu. m Obtained by Treating Butane in an Autothermic Generator

(a) Cost of Raw Material

The outlet gas is composed of:

91 per cent of reformed gas at 1,650 cal/cu. m	1,500 cal
9 per cent of gaseous butane at 30,500 cal/cu. m (3,430 B.t.u./cu. ft)	2,750 cal
Total	4,250 cal/cu. m

(4,250 cal/cu. m = 477 B.t.u./cu. ft)

The efficiency of reforming being at least 90 per cent, in order to obtain the 1,500 cal of reformed gas, $\frac{1,500}{0{\cdot}9} = 1,670$ cal of butane has to be used.

The total efficiency is thus at least:

$$\frac{4,250}{1,670 + 2,750} \times 100 = 96{\cdot}2 \text{ per cent.}$$

1 cu. m of reconstituted gas is thus obtained from 373 g of butane.

(b) Operating Cost for 1 cu. m of Final Gas at 4,250 cal/cu. m

Electricity consumption, 10 W/hr (at atmospheric pressure).

Steam, Process and surplus output for other purposes.

Boiler water, 0·23 kg.

Cooling water, 3 kg.

Catalyst, loss of 20 per cent of the charge per annum.

Hence, for a working period of 8,000 hr/annum, the cost is 0·0028 fr/cu. m.

Working and maintenance costs are very small, since the plant is fully automatic; for example, total annual expenses for materials, supplies, general equipment, salaries, and sundry expenses for a Works having an output capacity of 600,000 cu. m/day (21·2 mill. cu. ft/day) and having produced 100 mill. cu. m (3·5 bill. cu. ft/annum) amount to 2·5 mill. belgian francs (£17,000), or 0·025 fr. (0·04*d.*) per final cubic meter.

(c) Capital Costs of Plant

The cost of an autothermic gas production plant can be estimated at 1 mill. Belgian francs per 1,000 cu. m/hr. (£7,000/35 mill. cu. ft.).

(4) New Technique in Autothermic Catalytic Reforming

A new autothermic catalytic reforming process has just been tested in Belgium.

This process is based on the recuperation of the sensible heat of the reformed gases being pushed to a maximum. (See Figure 4.)

The mixture of hydrocarbon, oxygen (air) and steam is brought progressively to a temperature near to the temperature of reaction, by passing through recuperator checkers of special material.

The reactions take place on the catalyst. The reformed gas then passes through a checker recuperator identical to the first, which absorbs the sensible heat of the gas.

The process is cyclic: an inversion system changes the direction of the flow in the generator.

The production is, however, continuous; the use of an intermediate gasholder is not necessary.

This process can work under pressure and deliver the gas at the network pressure without intermediate recompression; only the air necessary for the reforming is, in this case, compressed, the steam and hydrocarbon being provided at the working pressure. Power economy is very important.

Heat recuperation is very high; the reformed gas at the outlet of the generator is about 50° C higher than the temperature of the mixture at the inlet.

Many advantages result from this, of which may be noted:

(*a*) The very high reforming efficiency of about 98 per cent.

(*b*) The reformed gas is, compared with gas from conventional autothermic reforming, of about 0·06 to 0·07 lower density and of about 350 to 400 cal/cu. m higher calorific value. These characteristics are very interesting from the point of view of interchangeability of gases.

(*c*) The robustness and simplicity of the installation, which has no high-temperature metallic circuits. The process steam has, however, to be provided separately.

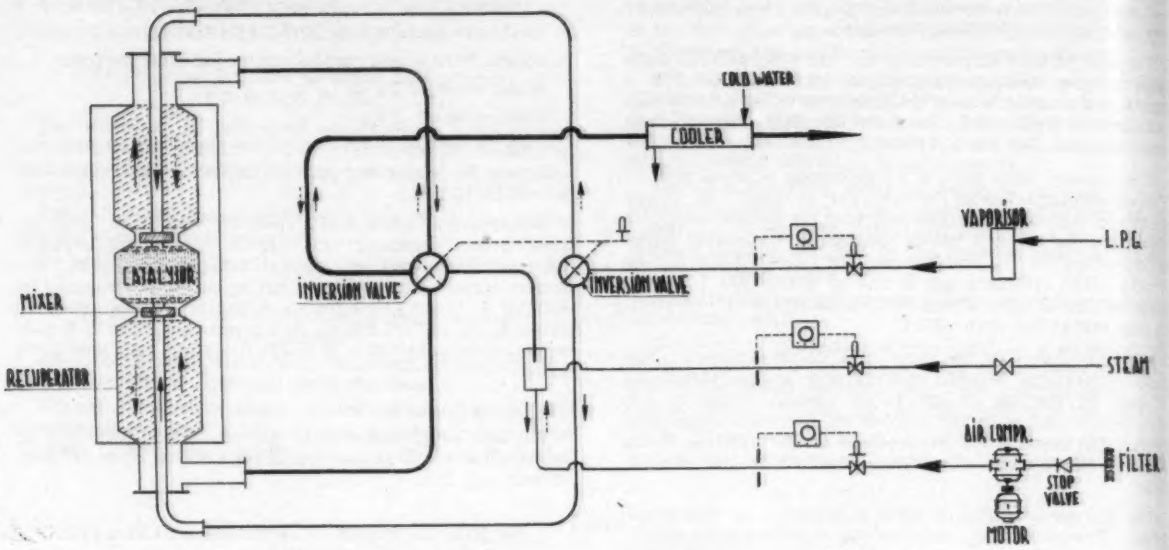


FIGURE 4.—*Flow Diagram for Autothermic Cracking.*

TABLE 4.—*Operating Results of Reforming with Air and Steam*

Gauge pressure, 1 atmosphere

Nature of hydrocarbon	Methane		Butane	
	Reformed Gas	Reconstituted Gas	Reformed Gas	Reconstituted Gas
1	2	3	4	5
Composition of the Gas				
CO_2	5·6	3·9	6·6	6·0
CO	14·3	10	17	15·6
H_2	43·3	30·3	40·5	37·2
CnHm	0	8	0	8·2
N_2	34·3	24·0	34·5	31·7
CH_4	2·5	31·8	1·4	1·3
Calorific Value (cal./cu. m.)	1,995	4,250	1,880	4,250
Density (Air = 1)	0·60	0·58	0·635	0·745
Efficiency (per cent)	0·98	0·99	0·98	0·99

APPENDIX

CALCULATION NOTES

Calculation of the conditions of equilibrium of the mixture:

$CH_4 = 1$ mole

Air $= 2{\cdot}6$ moles $(0{\cdot}54\ O_2 + 2{\cdot}06\ N_2)$

$H_2O = 0{\cdot}25$ mole

at different temperatures.

We have:

$\Sigma C = 100 \quad \Sigma O = 133 \quad \Sigma H_2 = 225 \quad \Sigma N_2 = 206.$

(*a*) Consider $f \neq 0$.

General equation (1) can be expressed by

$$100\,C + 133{\cdot}0 + 225\,H_2 + 206\,N_2 =$$

$$\left\{a + \overbrace{\left(\frac{133}{E} - 2a - i\right)}^{A} + \overbrace{\left(\frac{291{\cdot}7}{E} - 2a - 3i + 2f\right)}^{B} + \overbrace{\left(a + i - f - \frac{33}{E}\right)}^{C} + \frac{206}{E} + i\,H_2O + f\right\} E.$$

From this equation, we find:

$$i = \frac{133}{E} - 2a - A \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$B = 200 - A - \frac{770}{E} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$C = \frac{431}{E} + a + A - 100 \quad . \quad . \quad . \quad (8)$$

$$f = 100 - \frac{331}{E} - 2a - 2A \quad . \quad . \quad . \quad (9)$$

$$N_2 = \frac{206}{E}$$

Let us choose different temperatures in the probable area of reaction thus: 630°, 660°, 700°, 750° C.

For each of these temperatures, we know the values of the constants of equilibrium, thus $P = 1$ atmosphere.

T (°C)	$K1\,(T)$	$K2\,(T)$	$K3\,(T)$	$K4\,(T)$
630	0·447		15·85	$3{\cdot}16 \times 10^8$
660	0·544	$3{\cdot}98 \times 10^4$	43·6	$2{\cdot}01 \times 10^8$
700	0·65	$1{\cdot}26 \times 10^5$	108	
750	0·8	$4{\cdot}77 \times 10^5$		

K4 (T) is the constant of equilibrium of $CH_4 = 2H_2 + C$.

We now calculate for each of these temperatures the values of the products of reaction; thus, for $T = 660°$ C, having chosen an arbitrary value for A, such as $A = 14$, we then find:

$$a = \frac{A2}{K3(T)} = \frac{(14)^2}{43{\cdot}6} = 4{\cdot}5.$$

$$i = \frac{133}{E} - 9 - 14 = \frac{133}{E} - 23. \quad \text{(See (6).)}$$

$$B = 200 - 14 - \frac{770}{E} = 186 - \frac{770}{E}. \quad \text{(See (7).)}$$

From (2) $Ai = K1(T)\,a.B$, we have:

$$14\left(\frac{133}{E} - 23\right) = 0{\cdot}544 \times 4{\cdot}5\left(186 - \frac{770}{E}\right) \text{ of}$$

which we extract $E = 4{\cdot}82$.

$$B = 26{\cdot}4 \qquad C = \frac{430{\cdot}8}{E} + a + A - 100 = 7{\cdot}85.$$

We verify then that the value chosen for A is correct by comparing the ratio:

$$\frac{C}{B2} = \frac{7{\cdot}85}{(26{\cdot}4)^2} = 1{\cdot}13 \times 10^{-2}$$

with the value of constant $K4(T)$; thus, $2{\cdot}01 \times 10^{-2}$.

The value chosen for A being too high, the calculations are repeated with a smaller value for A. These operations are repeated until a value of the ratio C/B^2 sufficiently near to the value of $K4(T)$ is found; this is how the Authors obtained: $A = CO = 13{\cdot}05$. $a = CO2 = 3{\cdot}90$. $B = H_2 = 34{\cdot}29$. $C = CH_4 = 2{\cdot}37$. $N_2 = 40{\cdot}81$. $i = H_2O = 5{\cdot}58$. $f = 0{\cdot}51$. $E = 5{\cdot}04$. $Qs = 1{,}125$ cal. $Ql = 8{,}662$ cal.

If we do the same calculations with $T_{react.} = 700°$ C, we find $f < O$ (free carbon consumption). At equilibrium, this case is impossible, the equations cannot be used.

(*b*) Case where we consider: $f \equiv O$.

We can write in this case:

$$A = \frac{133}{E} - 2(a + 1) + 1 \quad . \quad . \quad . \quad (10)$$

$$C = a + i - \frac{33{\cdot}3}{E} \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$B = \frac{291{\cdot}7}{E} - 2(a + i) - i \quad . \quad . \quad . \quad (12)$$

$$N_2 = \frac{205{\cdot}8.}{E}$$

As the sum of the elements is equal to 100, we find:

$$\frac{597{\cdot}5}{E} - 2(d + i) = 100 \quad . \quad . \quad . \quad . \quad (13)$$

$$\begin{cases} T = 100° \\ P = 1 \text{ atmosphere} \end{cases}$$

we have $K1 = 0{\cdot}65$, $K2 = 1{\cdot}265 \times 10^5$.

We choose an arbitrary value for C, for example $C = 1$. From (11) we find

$$(a + i) = C + \frac{33{\cdot}3.}{E}$$

Introducing the value of $a + i$ in equation (13), we find:

$$\frac{597{\cdot}5}{E} - \frac{66{\cdot}6}{E} - 2C = 100, \text{ thus } \frac{100}{E} = 19{\cdot}2,$$

and then we find:

$$a + i = 7{\cdot}4, \; A = 10{\cdot}8 + i, \; B = 41{\cdot}2 - i.$$

From (2) $Ai = K1.a.B$ we extract the value of i

$$(10{\cdot}8 + i)\,i = 0{\cdot}65\,(7{\cdot}4 - i)(41{\cdot}2 - 1)\,i = 4{\cdot}4$$

thus $A = 15{\cdot}2$, $B = 36{\cdot}8$.

We now have to verify the value chosen for C; to do this, we calculate the ratio

$$\frac{A.B^3}{C.i} = 1{\cdot}715 \times 10^5$$

and compare the result with $K2(700°) = 1{\cdot}26 \times 10^5$; we thus see that the chosen value for C was too small. We do the calculations over again with a higher value and find after several trials: $C = CH_4 = 1{\cdot}22$. $A = CO = 15{\cdot}1$. $B = H_2 = 36{\cdot}3$. $a = CO_2 = 3$. $i = H_2O = 4{\cdot}7$. $E = 5{\cdot}18$. $Ql = 8{,}835$ cal. (See results in Table 1.)

PRESENTATION, DISCUSSION AND REPLY

Presentation

Monsieur J. Ribesse presented this paper and summarized its contents.

Discussion

Dr. F. J. Dent, O.B.E. (Director, Midlands Research Station, The Gas Council) :—With an abundance of hydrocarbons available, the ability to reform them has become of major importance, and the Authors are to be congratulated on an interesting and timely paper on the thermodynamics involved. It has particular reference to autothermic reformers designed to operate at high efficiency, with low plant costs, and it is not an abstract study, since the several plants already at work in Belgium are stated to have a combined output of 63·5 mill. cu. ft/day.

For the research man, reforming is an enthralling subject ; it bids fair to displace the classical Sabatier reaction for methane synthesis as the favourite exercise in thermodynamic relations. The same equilibria are involved, and, with the same high-activity catalysts, the equilibria are satisfied to all intents and purposes. From a process as well as from an experimental point of view, it is fascinating to be able to lay down, quite accurately, the conditions required to produce gas of a given composition.

The Authors have stated what is involved in the calculations and have expressed their results on an ingenious chart. I know from experience that, unless they have been blessed with a computer, quite a lot of midnight oil will have been burnt in preparing the curves of Figure 2.

Reforming covers a range of processes. At the one extreme, there is partial combustion with air, and, at the other, reaction with steam. The autothermic process described in this paper can definitely be regarded as of the partial-combustion type : for example, the partial combustion of methane to carbon monoxide and hydrogen theoretically requires 2·5 vol. of air, and, of the six curves in Figure 2, only one corresponds with a smaller air addition. The process can, therefore, be visualized as the passing of a mixture of hydrocarbon and air, with or without a small amount of steam, through a nickel catalyst on which the hydrocarbon is gasified by partial combustion in the air. The primary function of the steam appears to be to control the ratio of carbon monoxide and carbon dioxide in the products so as to avoid carbon deposition. As the ratio of air to hydrocarbon increases above the theoretical amount, carbon dioxide is produced by combustion and there is less need for steam addition, but the catalyst assumes a higher temperature and thermal efficiency falls as a result of greater losses of sensible heat in the products. Increasing the steam allows the

air supply to be reduced, to give a higher thermal efficiency, with the catalyst at a lower temperature, and, at the same time, it reduces the tendency for carbon deposition.

The operation of these effects can all be seen in the curves of Figure 2, which, as the Authors describe, are based solely on thermodynamic considerations, and, from what they say, they apply to the operation of large-scale plants now in use.

This rather surprises me. The indications of thermodynamics are undoubtedly of fundamental importance in pointing to the final state to which reactions progress, but they by no means tell the whole story, particularly in a system in which several reaction mechanisms occur. While the final state is laid down by thermodynamics, one has to arrive at it, and, in doing so, one is very much concerned with the relative rates of the various reactions—that is, with the reaction kinetics : for example, under conditions in which thermodynamics correspond with an absence of carbon deposition, deposition can, nevertheless, be encountered if the mechanism producing carbon occurs more rapidly than the carbon can be gasified, and this is likely to happen during the reforming of these hydrocarbons, which are thermally unstable as a result of containing more than one carbon atom per molecule. Because of this, it is usual to supply steam in excess and to bring the reactants rapidly to a high temperature so that the carbon will gasify in the steam, or, alternatively, as Mr. Percival is doing at Solihull, to have a preliminary stage in which the hydrocarbon is reacted with steam, in the absence of air, at a temperature too low for carbon to separate.

I should like, therefore, to ask the Authors whether the theoretical steam requirements given in the paper can be adhered to when using a hydrocarbon supply such as light distillate.

A diagram of the type of plant used is given in Figure 3, and some operating results for various feedstocks in Table 3. One realizes first that the plant could not be much simpler. It consists of little more than a vessel containing a bed of catalyst with heat exchange between reactants and products, and operation is continuous to minimize supervision and, at the same time, allow the precise control that is possible when reactions are proceeding to equilibrium. The heat exchange results in thermal efficiencies in excess of 90 per cent, while the plant cost, at 1 mill. francs for 1,000 cu. m/hr. or £8,300/mill. cu. ft per day, is certainly a very low figure. But the composition of the gas made by this simple version of an autothermic process has certain characteristics. Table 3 gives the composition of the gas leaving the reformer with the hydrocarbons having been more or less completely decomposed, and one notices the relatively high nitrogen content.

The theoretical nitrogen content for gas produced by the partial combustion of hydrocarbons with air is about 40 per cent, and it is seen that, except in the last two columns, which record the use of air enriched with oxygen, the nitrogen contents are not far removed from this value. There are, in addition, appreciable concentrations of carbon monoxide ; together, these account for the gas, even before enrichment, being of relatively high density.

Appreciating this, the Authors conclude with a description of a new design of reformer that aims at minimizing the air requirement and the introduction of nitrogen, by pushing heat exchange to the limit, using the regenerative principle.

A point that intrigued me here was that it was possible to preheat mixtures of hydrocarbons and air to reformer temperatures without interaction occurring. Perhaps this is due to the special material of which the checkers are made. Can the Authors enlighten one on this matter?

Table 4 shows that the new design has undoubtedly effected an improvement, and, indeed, with the thermal efficiency at the reformer increased to 98 per cent, the results are probably as good as can be obtained in a one-stage process using un-enriched air. But the hydrogen concentration in the gas from methane is still low for an adequate flame speed, while, in the case of butane, the density of the gas is still high.

Other speakers will no doubt comment on how such gases could be used, but I think I am correct in saying that, for the conditions in this country, such gases would have to be blended before distribution. One has in mind that there are alternative types of reformers, such as cyclic reformers, which reject nitrogen during the blow period, and externally heated reformers that allow the admission of air to be controlled.

At Solihull, this reforming problem is being approached with a rather different aim in view. The intention is to develop a reforming process with low plant costs, suitable for erection in high-capacity units for operation in conjunction with a pressure grid. In such circumstances, there might be little opportunity for blending, and it is taken that the gas produced by the reforming process must be completely interchangeable with that from our sources.

An examination indicated that, except when the feedstock was methane, the problem could be solved by an autothermic process, without using oxygen, if three features were incorporated : (i) the air requirements must be minimized as far as possible by thorough heat recuperation, a point that is, of course, stressed by the Authors in the paper ; (ii) the air requirement is reduced still further by operating the reformer at a relatively low temperature so as to produce gas of town gas calorific value directly : by doing so, additional heat is obtained from the exothermic conversion of part of the hydrocarbon feedstock to methane ; (iii) the gas density is reduced by incorporating conversion of carbon monoxide and removal of carbon dioxide.

Conversion of carbon monoxide and removal of carbon dioxide are admittedly a complication, but their disadvantage is lessened because of this. The need for the final gas to be under pressure calls for pressure operation. At pressure, the theoretical amount of steam required for reforming is increased, due to the greater tendency for the decomposition of carbon monoxide. The amount of steam needed is, in fact, sufficient for the conversion of the carbon monoxide, and the pressure is available for the removal of the carbon dioxide.

Plant costs, although increased, will still be relatively low if unit installations have capacities of 25 mill cu. ft/day or more.

The net result is that, when the three features are used, a gas of 500 Btu/cu. ft from butane contains 40 per cent of hydrogen and has a density of 0·46 as against the figure of 0·745 given in Table 4 of the paper.

Naturally, when the hydrocarbon feedstock is methane, no assistance can be obtained from the exothermic production of methane over the catalyst. For this reason, an autothermic process for methane really requires the use of air enriched with oxygen if the gas produced is to be completely interchangeable. The amount of oxygen needed can be minimized by good heat exchange, and, for a hydrocarbon such as methane, the highly efficient reformer described in the paper, if operated at pressure, might well be the solution.

Mr. G. U. Hopton (Senior Research Chemist, North Thames Gas Board) :—Many gas engineers have used butane/air mixtures during peak periods, but the disadvantage, of course, is the presence of oxygen, which causes corrosion of the mains when water is present. By using autothermic reforming, oxygen is avoided.

The first part of the paper deals with the theory of thermodynamic equilibrium.

The thermodynamic considerations lead to Figure 2, which gives the data for the reaction between methane, air and steam over a wide range of temperature, and, since the Authors have carried out similar work on butane, propane and light distillates, it would have been a great advantage to have had those curves, too. They would be so valuable.

When we come to plant results, there are many questions we should like to ask : for example, there is a point about the special mixer at the base of the generator. Some engineers know the difficulties due to bad flow pattern of gases through catalyst beds, which leads to hot spots. It affects the catalyst adversely and gives bad working results. Anything about this special mixer would be of value.

Nickel is not a particularly easy catalyst as regards the support where it is magnesia or alumina, but it must be remembered that in a continuous process like this, under reducing conditions, one would expect a nickel catalyst to withstand conditions rather better than in a cyclic process.

To my mind, the most interesting part of the paper is the description at the end with regard to the new technique using regenerators. Dr. Dent has mentioned this. What temperature is obtained at the outlet of the regenerator before passage through the catalyst, and does any reaction in fact occur in the regenerator? The results are not merely good : they are spectacular. There is

very high efficiency, and the density of the gas is about 0·06 lower than that from conventional autothermic reforming. Also, the calorific value is about 40 Btu/cu. ft higher. But the gases still contain a good deal of nitrogen, and the specific gravity is high, so that interchangeability must still be carefully studied.

The costs given in the paper, converted to British units, as Dr. Dent has already said, amount to £8,300 for a plant of 1 mill. cu. ft/day capacity. This is so low that, if it is true, the best thing one can do is emigrate to Belgium straightaway!

I should like to ask the Authors : Can one really buy a plant for £8,300 to turn out 1 mill. cu. ft/day of gas? Or, if this is a silly question : At what size of plant does this rate of costs apply?

Some calculations done by my colleagues and me showed operating costs estimated at 0·1*d.*/therm ; if the capital costs are as low as stated, then the capital charges would be another 0·1*d.*/therm, so the cost of this gas-making process would be the cost of the feedstock calculated at 92 to 98 per cent efficiency, plus 0·2*d.*/therm capital charges and operating costs. This is so low that it is a very attractive process, and I am very grateful to the Authors for bringing it to our attention.

Dr. M. J. F. Olden (Area Chemical Engineer, South Western Gas Board) :—Much of what I should have liked to have said has already been said.

Apart from being an invaluable contribution to one's knowledge of hydrocarbon reforming, the paper presents, in a lucid and logical sequence, the steps to be taken when calculating the quality of the anticipated product during an autothermic reforming reaction. It is refreshing to find that the Authors have given sufficient information for their calculations to be checked. I cannot disagree with any of the calculations they have shown.

Autothermic reforming is a process that is relatively novel in the United Kingdom. The gas produced from any of the plants that have been proposed during the past decade varies considerably in properties from town gas as we know it today. There are other considerations than specific gravity to be taken into account when assessing how much gas of this nature can be successfully admixed with the more conventional gases produced on gas works, but, as gas engineers know, any efficient process that requires only a low capital outlay is attractive where peak loading is concerned. The Authors clearly indicate that they consider the processes outlined in the paper to be for peak loading only, where one is considering town gas.

Examining the analyses given in Table 3, it can be seen that the lean gases produced solely by reforming possess a relatively high specific gravity, which, in itself, may not be increased when the gas is enriched by the addition of methane or liquefied petroleum gases. It would seem that, so far as the British gas industry is concerned, the product from the Distrigaz plants would lie between primary flash distillate enriched and reformed water gas and producer gas, in the matter of gas interchangeability. Nevertheless, I do not wish to appear pedantic in this matter : these processes are peak processes and the account given in the paper undoubtedly makes interesting reading.

The South Western Gas Board, in collaboration with the Woodall-Duckham Company, has studied another type of reformer, namely, the Koppers-Hasche, which allows for both cyclic and autothermic reforming of light petroleum distillates. Those who visited Gloucester during the period of experimentation will know that, so far as the production of a cyclic gas completely interchangeable with coal gas is concerned, a great measure of success was achieved. Unfortunately, as is often the case, the process was defeated by side considerations such as the removal of fly carbon, for which no satisfactory solution was found.

At this stage, I should like to mention that we were unsuccessful in implementing the calculation principles discussed in the first part of the Authors' paper, due to the complexity of the hydrocarbons produced during the work and, as a consequence, the very large number of reaction equations involved.

Although our work on autothermic reforming met with only a modicum of success, a brief indication of our findings would be of some interest.

The Koppers-Hasche reformer involved only the use of air and a light distillate of specific gravity of 0·66. There was no catalyst and no steam involved in the reaction. I say advisedly that there was no catalyst, because we were not aware of any catalytic activity shown by the alumina tiles forming the core of the plant. As a result of our preliminary work, a run of approximately 400 hr duration took place, in which a gas of average calorific value of 690 Btu/cu. ft and specific gravity of 1·07 was manufactured. During this run, attempts were made to lower the calorific value, but fly carbon interfered with the process once more. Any attempt to increase the calorific value by a lowering of the average working temperature, which was about 640° to 650°C, resulted in the production of a highly unstable gas that lost heavily in calorific value upon compression, due to the deposition of hydrocarbons. In one instance, the application of a pressure of 50 lb/sq. in. caused a loss of 150 Btu/cu. ft. So we were " caught between two stools " : one a difficulty with carbon at a calorific value of 670 Btu/cu. ft. or below, and one the production of an unstable gas at 700 Btu/cu. ft and above. The process was abandoned as it could not be guaranteed that the quality of light distillate being received would remain constant, and the very narrow range of calorific value in which the gas was in any way usable would undoubtedly vary with the properties of the feed. Apart from these considerations, it seemed that, no matter how well instrumented or automatic the process could be made, there could be no guarantee that the process would not slip, however temporarily, into the undesirable ranges of calorific value, and either cause the plant to shut down, due to carbon blockage, or, worse still, deposit highly undesirable oils throughout a works system. In passing, it is interesting that, if one dismisses the grave disadvantages of autothermically reforming light distillates on the Koppers-Hasche plant, an efficiency of approximately 92 per cent was achieved. All that I have said applies only to light distillates, and the Koppers-Hasche autothermic process is well established across the Atlantic on a feed of butane and propane. It appears, therefore, that the catalytic process may have much to commend it over the non-catalytic process tried out in the South Western Area.

In spite of the encouraging figures given (Table 3,) for the use of light distillates, I am tempted to remark that there is adequate lean gas available in the industry today, and, if one is to operate a process, such as those described, to the maximum effect, one would presumably require a hydrocarbon gas for enrichment. In certain areas, this might prove embarrassing, but where refinery gases and—dare I say?—methane are readily available, I believe that the Distrigaz process could bear very critical examination if it were decided to install any new peak-load plant.

In conclusion, I would draw attention to the second line of the first paragraph in the Summary. Herein lies the Achilles' heel of all peak-load autothermic processes. If one could reform with oxygen instead of air, many, if not all, of the criticisms of the gas produced would disappear. All gas engineers know that the provision of oxygen is at the present time a financial impossibility for peak-load plants. I have many years ahead of me in the gas industry, and I hope that, some day, I shall see the autothermic principle applied to small units under the very best conditions, namely, the reaction between hydrocarbon, steam and nitrogen-free oxygen.

Mr. C. Ryder (Process Development Chemist, Central Laboratories, South Eastern Gas Board) :—I shall limit my comments to one or two questions to the Authors.

When producing similar curves, as they have produced in Figure 2, for light distillates, do they take the whole range of light distillates, or take a typical member, such as C_6H_{14}, as a basis for their curves?

Another point that I think is of some importance is, the ability to assess whether equilibrium has been reached in the reactor, when comparing theoretical results with practical results. Have the Authors found this to be the case? If regeneration is practised, the whole matter becomes much more complicated, because, when the reactants pass through the regenerator, the temperature of the gaseous mixture is continuously altering ; hence, the equilibrium composition of the gases changes. This would also be applicable to cyclic plants, particularly with a deep catalyst bed such as is used in the Segas plant, where temperature differences within the catalyst bed prevent a theoretical assessment of the reaction temperature.

The cost of gas produced by the Distrigaz process has already been mentioned by other speakers : I would commend the industry to consider whether the use of liquefied petroleum gases as feedstock would not be cheaper than producing producer gas from coke.

Written Contribution

Mr. V. Brunchmann (Haldor Topsœe, Denmark) wrote :—The first process appears to be rather similar to those developed by other firms. This type of process is admittedly used for low-pressure autothermic reforming of various hydrocarbon stocks ; at higher pressures, however, we doubt that satisfactory operation can be obtained in this way, but we realize that high-pressure operation is normally of less inherent interest to the gas industry than to the chemical industry.

The same argument is more or less valid for the recuperative autothermic reforming process described later in the paper. Besides, we have some doubt with regard to the idea of passing a mixture of hydrocarbons, air and steam through a recuperator where the temperature is about 700° to 800°C, and then contacting the mixture directly with the catalyst. In general, we consider flameless surface combustion of liquefied petroleum gas to be difficult.

By both processes, a gas containing a rather high amount of inerts, in particular nitrogen, is produced when air is the only source of oxygen. Obviously, this is an inherent feature of any autothermic reforming process, but in cases where rich gas of the proper composition is available for Btu-adjustment, and where town gas specifications are favourable, autothermic reforming with air may become an attractive possibility ; this has, for instance, been the case at the Copenhagen Gas Works. When oxygen is available, it becomes, of course, easier to satisfy town gas specifications.

The process developed by Société Belge de l'Azote et des Produits Chimiques du Marly and ourselves has the merit of being able to work at pressures up to 400 lb/sq. in. gauge and on all kinds of gaseous and liquid hydrocarbon feedstocks, including light paraffinic naphtha. This autothermic and catalytic process can use pure oxygen as well as enriched air, or simply air, and is, therefore, well suited for the production of gas for the synthesis of, for instance, ammonia and methanol, but in many cases the process may also come into consideration for town gas production. At the present time, one unit has been running successfully for about two years on commercial liquefied petroleum gas at the plant at Marly, and another unit has recently been put on stream for the manufacture of ammonia synthesis gas from natural gas at the Kuhlmann plant at Paimboeuf.

With regard to the process calculation method outlined in the paper, this method has certainly some merit when used for the study of a specific problem with several parameters. We have used a very similar method ourselves for such a study some years ago, but since we have developed a programme for electronic computation, which basically solves the same equations, but in much less time, we find this programme more convenient to use. In fact, the electronic computer is able to make a complete process calculation for an autothermic reforming unit in less than 2 min. when it is operated according to our programme.

Written Reply

The **Authors**, in reply, wrote :—The results obtained with pilot generators and also with industrial generators are very near to the calculated ones based on thermodynamic relations. Although these calculations are based solely on thermodynamic equilibrium relations, and do not take into account reaction kinetics, the velocities of reactions being high through the use of very active catalysts, the differences between actual and theoretical states are small.

Calculations established for heavier hydrocarbons such as butane, pentane, hexane, are just as useful as the others. But in order to avoid carbon black formation, it is safer to be sufficiently far from the theoretical calculated limits indicated by the diagrams because actual results, though near the theoretical results as indicated, can differ from the latter for several reasons, such as velocity of reaction depending on the catalyst, more or less accurate mixing and variations in the proportions of fluids at the changes of output, loss of radiating heat of the generator bringing the temperature of reaction locally to a level that cannot be calculated, *etc.*

New Technique.—So as to avoid preliminary reactions the preheating at a high temperature of the air-steam-hydrocarbon elements is done separately before mixing, which occurs at high temperature just before the catalyst bed. This disposition allows the production output to be changed quite appreciably because there is no necessity to maintain velocities above those of reaction occurrences.

Quality of Gas Obtained.—The cracked gas obtained in autothermic processes is rather heavy ; this is why it is not used alone in the classical town gas distribution grid.

Nevertheless, its flexibility and cost price make it a good peak-load gas.

With no inconvenience concerning interchangeability, it can be blended in equal part with classical basic gas, which allows one to follow variations in the gas demand. The cost price of such a gas is appreciably lower than the price of gas obtained in cyclic or continuous steam processes, because of high gasification efficiency and low capital cost.

The thermodynamic diagrams such as Figure 2 have been traced in a detailed way only for methane and butane. Only a few points of such a diagram have been determined in the case of the heavier hydrocarbons.

In the new technique, the temperature at the outlet of the generator is about 100°C. The mixing of the air, steam and hydrocarbon is done at the base of the catalyst bed at a temperature of about 650°C.

The average temperature of the catalyst is about 720°C.

The capital cost indicated applies to plants having a maximum output of 6,000 cu. m/hr (227,000 cu. ft/hr) and 12,000 cu. m/hr (454,000 cu. ft/hr).

The smaller plant (one oven) thus costs B.fr. 6 mill. (£43,000).

The larger plant (two ovens) costs B.fr. 12 mill. (£86,000).

For calculating equilibrium conditions, pure hydrocarbons were considered, such as C_4H_{10} or C_6H_{14}, for light distillates.

When assessing whether equilibrium has been reached in the reactor, one has, of course, to consider averages ; if, however, the catalyst bed is not very deep, temperature differences are small. In the case of the new technique, no reaction takes place in the recuperator.

Proceedings of Council

The following matters of general interest were among those dealt with by the Council :—

COUNCIL MEETING 18th JULY, 1961

The annual review of the membership of the Committees of the Council was undertaken and consideration was given to the representation of the Institution on kindred organizations. The Council agreed additions and alterations where appropriate.

Reports were received of meetings of the following Committees of the Institution :—

(1) COMMITTEE ON UNACCOUNTED-FOR GAS, on 3rd May, 1961.

(2) GAS DISTRIBUTION COMMITTEE, on 4th May, 1961, and on 12th July, 1961.

(3) METERS COMMITTEE, on 20th June, 1961.

(4) CODES OF PRACTICE SUB-COMMITTEE, on 17th July, 1961.

(*a*) A revision of the Code of Practice CP.332.201 (Domestic Hot Water Supply by Gas) was considered and agreed in principle, but a number of matters of detail were referred back to the Drafting Panel for further discussion.

(*b*) A revised Code of Practice CP.332.401 (Selection and Installation of Domestic Gas Cooking Appliances) was approved, subject to minor amendment, for submission to the Council for Codes of Practice.

(*c*) It was agreed that two codes of practice are necessary to deal adequately with " Installation of Gas-fired Boilers for Central Heating by Hot Water," one to cover installations up to approximately 150,000 Btu/h and a second to deal with larger installations.

A report was received of the 8th International Gas Conference held in Stockholm on 27th to 30th June, 1961. The British representation had been the largest present and British delegates had taken an active part in the discussions of papers and reports presented.

The Council appointed Dr. A. E. Haffner, B.Sc., as a representative of the Institution on the Council of the International Gas Union.

A report of the Health Congress held at Blackpool on 24th to 28th April, 1961, was received from Mr. D. M. Thompson who had attended as the Institution's representative.

Reports were made by the official representatives of the Institution who attended the Annual General Meetings of the following overseas Gas Associations :—

Belgian Gas Association in Brussels on 7th and 8th June, 1961. (President and Secretary.)

French Gas Association at St. Malo on 12th to 17th June, 1961. (President and Secretary.)

German Gas Association in Berlin on 28th to 31st May, 1961. (President, Former Secretary, and Secretary.)

Netherlands Gas Association at Eindhoven on 10th to 12th July, 1961. (Immediate Past President.)

Binding of the Journal

Arrangements have been made for binding annual volumes of the *Journal* to members' order. The December, 1961, issue will contain an index to the volume for 1961 and an order form, which readers will be able to send to the binders along with their copies of the 12 monthly issues and a remittance of £1 8*s*. The binders will remove the paper covers and advertising matter from each issue and will bind the remaining text into a blue buckram cover similar in appearance to those formerly used on the bound volumes of the *Transactions* of The Institution of Gas Engineers. This cover will be embossed in gold with the crest of the Institution and an appropriate title. A title page will also be inserted in the bound copy.

The binding will be undertaken by Straker Brothers, Limited, who are also the printers of the *Journal*. For readers who wish to make their own arrangements for binding the *Journal*, it will be possible to obtain the embossed binding cases separately from Straker Brothers, at 8*s*. each.

Consideration is being given to an alternative arrangement for subsequent volumes of the *Journal*, whereby members could reserve, *in advance*, each year, a bound copy of the *Journal* which would be additional to their monthly issues (which would be posted as usual). The material for this bound volume would be laid aside by the printer each month, thereby assuring its preservation in good condition, and would be bound immediately after the December issue had appeared. Members would thus receive, at the end of 1962, a bound copy in perfect condition, and their monthly issues would still be continuously available. They would also be saved the trouble of posting copies back to the printer for binding at the end of the year. It is estimated that the cost of a bound volume prepared in this way would be £1 13*s*., but *it must be emphasized that this service would be available only to subscribers to the monthly issues, and bound copies will not be sold separately*. This second method would require firm orders for the additional bound volumes to be placed at the beginning of each year, and it is requested that readers who contemplate adopting this procedure for 1962, should write *now* to the Secretary, The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1. If it appears that sufficient demand exists for this service, arrangements will be made with the printers.

Readers who wish to have their own copies bound at the end of the year, need take no action until they receive the December, 1961, issue of the *Journal*, which will contain an order form and full instructions.

News from the Gas Industry Overseas

The full text of articles abstracted below may be consulted in the Library of the Institution.

Development of the Gas Industry

Gas Wasser Wärme, June, 1961, 117-119.

Comparative figures for the whole of Austria, for the years 1959 and 1960, are given :—

	1959	1960
Coal to Gas Works (thou. tons)	344·4	342·0
Gas Distributed (mill. m³)	988·0	1,392·9
Coke Produced (thou. tons)	269·8	262·5
Tar Produced (tons)	13,908·0	13·858·0
Number of Consumers (thou.)	794·4	806·0

Both the number of consumers and the consumption per consumer have increased. There is a continuing transition from the use of coal to that of hydrocarbons (natural gas, liquefied petroleum gas) for gas manufacture. In Vienna, where there was a 10 per cent increase in gas supply compared with the previous year, new plants for cracking natural gas have been installed. Other towns where new installations for producing town gas from natural gas, liquefied petroleum gas or heavy oil have been erected or are planned, include Innsbruck, Salzburg, Graz, *etc.* Notable increases have also been recorded by the two companies responsible for the long-distance transportation of natural gas in Austria.

Comparative Study of Catalysts Used in the Gas Industry

Vignes and Cottin. Ass. Tech. de l'Ind. du Gaz en France. Congrès, 1961.

The catalysts examined contained from 2 to 15 per cent of nickel deposited on a refractory support. They were subjected to comparative tests of their physical properties (porosity and mechanical strength) and of their activity. The latter, termed " Catatest ", uses the reaction of reforming natural gas with steam in a continuous process with external heating at 800°C. The results, for a series of 16 catalysts, indicated that :

(*a*) activity is sensibly proportional to the nickel content, with an optimum at 6 to 9 per cent,

(*b*) activity is sensibly proportional to the pore volume, starting from a minimum of about 0·18 cm³/g,

(*c*) activity is also related to the volumetric concentration of nickel.

Details are given of the test apparatus, preparation of sample, and operating conditions. The advantages and disadvantages of the method are discussed, together with the actual results obtained, which are illustrated by numerous graphs. The study of the variation in catalyst activity with operating conditions (steam: gas ratio, flow rate, contact time, *etc.*) has enabled the optimum conditions of their use to be determined. Comparisons are also described between tests carried out in continuous and cyclic operation.

Formation, Elimination and Determination of Traces of Iron Carbonyl and Nickel Carbonyl in Gas from the Underground Storage at Beynes

C. Degent and C. Lebras. Ass. Tech. de l'Ind. du Gaz en France. Congrès 1961.

The presence of iron and nickel carbonyls in the gas withdrawn from the underground storage at Beynes was discovered as a result of complaints of the formation of deposits on burners and of opaque spots in glass during fusion. The formation of the iron carbonyl from the carbon monoxide in the gas and the metal of the piping has been traced to the catalytic action of formic acid present in the water in the storage area, but the origin of this acid and the process of formation of nickel carbonyl have not yet been explained. Metal carbonyls can be removed by chemical or physical means, but the only practicable industrial method has been found to be adsorption on active carbon, success depending upon a strict control of the quantity of moisture present. Nickel carbonyl is much less readily adsorbed than iron carbonyl. The adsorbant is easily regenerated by steaming out the carbonyls, without decomposing them, and then carefully drying the carbon. By applying the results of this experimental work, it was possible to supply from the underground storage at Beynes, during the winter of 1960-61, more than 1·5 mill. m³/d of gas without any kind of incident due to metal carbonyl. The paper includes an illustrated description of the purifying plant at Beynes, together with notes of methods for determining traces of iron and nickel carbonyl in gas.

(*a*) **Experimental Station at Nantes for the Liquefaction of Natural Gas and the Storage and Regasification of Liquid Methane.** L. Richard and M. Biais.

(*b*) **Underground Storage of Liquid Methane.** J. Toche.

Ass. Tech. de l'Ind. du Gaz en France. Congrès, 1961.

The first paper gives a detailed description, with photographs and drawings, of the installation that has been in operation at Nantes since July, 1960, in connexion with proposals for the transportation by sea of liquid methane. The capacity of the liquefaction plant is 10,000 m³/24 h of gas (17 m³ of liquid gas), and the storage tank, made of a special nickel steel, holds 290,000 m³ (500 m³ of liquid). The problems investigated include suitable materials for the storage tank and its insulation, a theoretical and practical consideration of mechanical strains on materials at low temperatures, variation in the composition of the liquid gas in storage, pumps and ancillary plant for handling liquid methane under pressure, regasification, and safety devices.

The second paper discusses theoretical, laboratory and semi-industrial investigations of the storage of liquid methane at −160°C and atmospheric pressure in an artificial underground cavity. The many factors considered include a study of temperature distribution in the surrounding ground under transitional and equilibrium conditions, the thermal and mechanical properties of different rocks and their behaviour under thermal strain, and the mechanical stability and gas-tightness of a cavity whose walls are subjected to steep temperature gradients. In order to check if the data obtained can be applied to the planning of industrial-scale storages, tests are at present being made on three experimental cavities, with a capacity of about 25 m³ each. So far, the results are encouraging.

(*a*) **Contribution to the Study of the " Se-Duct ".** R. Liard and M. Pérou.

(*b*) **The " Se-Duct " in Collective Apartments.** P. Richalet. Ass. Tech. du l'Ind. du Gaz en France. Congrès, 1961.

After describing the " Se-Duct ", and the pioneer work on it in Britain, the authors of the first paper consider theoretically the calculation of temperatures and draught along the duct, resistance in the duct and effect of wind. They then report detailed results of trials made with a test duct at Gennevilliers and at a 10-storey block of 160 apartments at Cholet. These trials have confirmed the satisfactory performance of the duct, its flexibility and capacity and its complete safety when used with appliances of the sealed combustion circuit type.

The second paper deals mainly with constructional details of the " Se-Duct ", the elements of which it is built up and its installation. Reference is made to the types of appliances suitable for connexion with the duct, the economical aspect of the system, and touches on regulations relating to the installation of the " Se-Duct ". Further particulars, with photographs, are given of this test installation at the block of flats at Cholet, which is 115 ft high. Other ducts are being installed at Elbeuf (210 ft) and a 23-storey building at Marseilles (about 220 ft).

Use in the Gas Industry of Vapour-phase Chromatography at a High Temperature

M. Boivin. Ass. Tech. de l'Ind. du Gaz en France, Congrès, 1961.

An account is given of a method of high-temperature vapour-phase chromatography, which is particularly useful for the analysis of small samples of mixtures of sparingly volatile substances met with in the gas industry ; e.g., various types of tar and of petroleum oils. Owing to their low vapour pressure, a heated column is required and the detector must also be heated to avoid any condensation. The temperature along the column need not be strictly uniform so long as it does not vary with time. Examples are given, illustrated by chromatograms, of the application of this method to the examination of gas-conditioning oils, oils extracted from old rubber joints, various heavy condensates obtained in gas installations and particularly in gas mains, and odorants. Reference is made to special procedures for preparing the samples for analysis.

In this Issue...

F. J. Brewer

H. N. Ballantyne

J. Ribesse

Ch. Van Maele

F. J. Brewer received early engineering training at The Polytechnic, Regent Street, London, and Westminster Technical College. He has held various appointments in the Parkinson Cowan Group, and at one time was Divisional Director of the Gas Meter Division. Subsequently, he was appointed Director-in-Charge, Parkinson Cowan Industrial Products.

H. N. Ballantyne, M.A., read Physics, Chemistry and Mathematics at Oxford before the Second World War, which led to a degree in 1940. He returned to Oxford after the war, and took an honours degree in Engineering. He joined the Parkinson Cowan Group as a post-graduate trainee in 1947, and served as production engineer and development engineer of gas appliances prior to his present appointment as Sales Manager of Parkinson Cowan Industrial Products.

J. Ribesse graduated Technical Engineer in 1950 at the Université du Travail, Charleroi, and holds the Certificate des Hautes Etudes Gazières à Gaz de France. He joined Distrigaz, S.A., Belgium, in 1952, with which company he has participated in the design and construction of cracking plants.

Ch. Van Maele graduated Technical Engineer in 1959 at the Ecole Centrale des Arts et Métiers, Brussels, and joined Distrigaz, S.A., Belgium, in 1960.

Personal Notes

Appointments

(*a*) *By Area Gas Boards :*

NORTH EASTERN GAS BOARD
Leeds Group—
General Manager : **J. G. Tilley**
Hull Group—
Goole and Selby Works—
Works Manager : **S. Dobbs**

EASTERN GAS BOARD
Watford Division—
Luton District—
Deputy District Manager: **L. F. Skinner**

(*b*) *General :*

Mr. R. B. Garside (M) is now in private business in Milnthorpe.

Mr. D. J. Homyer (AM) has been appointed Assistant Lecturer at East Ham Technical College.

Mr. W. E. Jakeman (AM) has been appointed Lecturer at the College of Further Education, Newcastle-upon-Tyne.

Retirements

Mr. E. L. Farquhar (M) has retired from the Production Staff, Wakefield Group, North Eastern Gas Board.

Mr. J. A. Fursey (A) has retired from his position as Group Special Representative, Wellingborough District, East Midlands Gas Board.

Mr. G. W. Perks (M) has retired from his position as Deputy General Manager, Tees-side Division, Northern Gas Board.

Addresses Required

The Council would be grateful to receive the present addresses of the following members, last heard of in the places given in brackets :

Mr. W. G. Bignell (Eastbourne).
Mr. D. J. Bradley (London).
Mr. E. Clark (Bridlington).
Mr. S. W. Hayes (Braunton).
Mr. P. W. Hugh (Middlesbrough).
Mr. C. Kay (Cambridge).
Mr. N. P. Shepherd (London).
Mr. A. W. Somerville (Bury).
Mr. A. M. Steel (Gutersloh, Germany).
Lt-Col. T. C. Whimster (Ashford).
Mr. W. D. Wright (Swindon).

District Sections and Affiliated Associations

(a) Notes of Meetings

DISTRICT SECTIONS

London and Southern Section

The Summer Meeting of the London and Southern Section was held at Gorhambury, St. Albans, Hertfordshire, on Tuesday, 20th June, 1961.

In the morning, some 150 members, guests and their ladies visited the old Roman city of Verulamium including the museum, the Roman theatre, and the hypocaust.

Later, the party assembled for luncheon at the Public Hall, Harpenden, where the guests included the Chairman (Mr. M. Milne-Watson, C.B.E.) and Deputy Chairman (Dr. J. Burns, G.M.) of the North Thames Gas Board, the Chairman of the Eastern Gas Board (Mr. J. H. Dyde, O.B.E.), the President of The Institution of Gas Engineers (Mr. T. C. Battersby, M.B.E.), the Secretary of the Institution (Mr. A. G. Higgins), and their ladies. On this pleasant occasion, the toast to the London and Southern Section was proposed by Mr. Michael Milne-Watson, C.B.E., and Mr. J. A. Hepworth (Chairman of the Section) replied.

In the afternoon, the guests, by kind permission of the Earl of Verulam, visited Gorhambury, the ancestral home of the Grimston family. Lady Verulam welcomed the guests, who had the opportunity of inspecting the house, famous for its paintings (particularly portraits) and other works of art.

Later, tea was served in the grounds of Gorhambury to conclude a most delightful and interesting visit and an enjoyable Summer Meeting favoured by excellent weather.

Midland Section

The Summer Meeting (Ladies' Day) of the Midland Section was held at Walsall on Friday, 23rd June, 1961. After assembling at Pleck gas works, the ladies visited Dudley zoo while some of the members toured Pleck gas works and the remainder inspected South Staffordshire Mond gas works.

Luncheon was served at the Town Hall, Dudley, at the kind invitation of the East and West Midlands Gas Boards. Amongst the guests were the Mayor and Mayoress of Dudley (Councillor H. Pritchard and Mrs. Pritchard), the Deputy Mayor and Mayoress (Alderman C. N. Preedy and Mrs. Preedy), the Town Clerk (Mr. P. D. Wadsworth), the Chairmen of the East and West Midlands Gas Boards (Mr. R. S. Johnson, M.B.E., T.D., and Mr. G. le B. Diamond, C.B.E.), the Junior Vice-President of The Institution of Gas Engineers (Mr. W. Hodkinson, O.B.E.) and Mrs. Hodkinson, and Mr. and Mrs. A. F. Oatley.

After the Loyal Toast, proposed by the Chairman of the Section (Mr. F. Harvey), the toast of " The County Borough of Dudley " was proposed by Mr. G. le B. Diamond, C.B.E. He expressed his pleasure at the presence of the Mayor and Mayoress, and welcomed the other guests. Mr. Diamond referred to the fine history of the ancient Borough of Dudley and to the caverns that lie beneath the town and which, although unique, gave great anxiety to the local authority and, indeed, to the West Midlands Gas Board. He recalled past happy associations with the former Dudley Gas Company, which had been so capably managed by Mr. F. Briggs, now retired. He thanked the Mayor for the very warm welcome that had been extended to members and their ladies and for the co-operation that had always throughout the years been so readily given by the local authority.

Responding, the Mayor of Dudley welcomed the members of the Midland Section and their ladies, but regretted that the visit, by reason of the very full programme, would be a short but, he hoped, an enjoyable one. He stated that he was pround of the town's achievements, particularly the large " Clean Air " area that had been developed, as a result of which he felt that the term " Black Country ", of which Dudley had been described as the capital, was now a misnomer. He referred to the town's long association with the gas undertaking, which, under the private company, had extended from 1820 to 1949. They were proud of this association, which had always been a happy one and still was.

Mr. W. Hodkinson, O.B.E. (Junior Vice-President of the Institution) proposed the toast of the Midland Section. He first apologized on behalf of the President and Senior Vice-President for their inability to attend due to considerable pressure of business, and expressed appreciation that his first " airing " as Junior Vice-President should be in the town of Dudley. He referred to Mr. Harvey as a man of great ability and pride as well as an enthusiast with a great desire that the Section should play an increasing part in the work of the Institution, and who, as Chairman of the Section, was entering into a year of great challenge. He followed a long line of illustrious Chairmen and Presidents, but he had no doubt that Mr. Harvey would prove himself as they had done. He extended to Mr. Harvey best wishes on behalf of the Institution, and expressed the hope that Mr. Harvey would enjoy his year of office, and assured him that he would receive all the support he required from the members.

In responding, Mr. Harvey thanked The Institution of Gas Engineers for their constant support, and the East and West Midlands Gas Boards for their hospitality and assistance, not only throughout the years, but particularly for this Ladies' Day. He stated that the Section continued to flourish with the help of the two Boards and outside sources. The Section had never been short of support from local industrial firms, both those that manufactured gas appliances and those to which gas was supplied. He thanked Cannon Iron-foundries and Accles and Pollock, of the T.I. Group, for making the visits to their works possible. He also thanked his own staff for their efforts in making the day a memorable one.

In conclusion, he mentioned the approaching retirement of Mr. G. le B. Diamond, C.B.E. (Chairman of the West Midlands Gas Board). He believed that this was the last occasion when he would, as Chairman of the Board, be present at a function attended by ladies, and expressed on their behalf very best wishes for a happy retirement and good health for Mr. and Mrs. Diamond.

Mr. R. S. Johnson, M.B.E., T.D. (Chairman of the East Midlands Gas Board) said he wanted to say how much they had esteemed Mr. Diamond, and he asked the company to drink the health of the Chairman of the West Midlands Gas Board.

(b) Abstracts and Discussions of Papers

Copies of the complete papers abstracted below are available for consultation or loan in the Library of the Institution.

DISTRICT SECTIONS

Eastern Section

"Improving Our Competitive Position", *by J. H. Dyde, O.B.E., M.Sc., M.I.Gas E., M.I.Chem.E., Chairman, Eastern Gas Board.*

Address delivered at Great Yarmouth on 3rd June, 1961.

Competition in the fuel industry is intensifying, and how best to improve the competitive position of the gas industry's commodity against other fuels formed the basis of the address.

There were two self-evident ways of approaching this problem : the first obvious way was to look at the costs of producing gas. The second obvious way was to look at the economies that might be made in all other costs that go to make up the price of gas delivered to the consumer.

Certainly to the Eastern Gas Board, there was the long-term approach to a reduction in gas production costs by the introduction of new techniques—by large-scale high-pressure gasification plants sited in or near the colliery areas from which suitable coal might be available, the equally large-scale gasification and reforming plants sited for ready access to petroleum products as their raw materials, and the importation of natural gas. Any day now, the Gas Council's scheme for the importation of methane would go before the Minister ; it was the most imaginative and enterprising scheme ever produced by the gas industry, and the Author could only hope that its economic advantages would prevail against the political and strategic arguments that would be advanced against it, particularly as the Eastern Gas Board was involved, in relation to its gas demand, possibly more than any of the other seven Boards concerned. Of all the alternatives investigated, a supply of methane would provide the industry with the cheapest possible gas with the right sort of characteristics, and would place it in a strong position to meet any future competition, be this from oil or the direct use of liquefied petroleum gases.

The Eastern Gas Board was favourably situated to receive methane, for the proposed distribution main to serve the several Boards concerned would run across part of the Board's southern territory before passing north-west, and it could supply the Midlands coal-gasification plants with enrichment gas, *en route*. Under this scheme, methane would be reformed at Dunstable, Hertford and Norwich, and, after mixing with the products of existing plant, would provide a gas containing less carbon monoxide than at present.

The new Otto plant being erected at Dunstable would start on butane or propane, but could readily be switched to methane.

Whichever plan or combination of plans was chosen, gas would come to the Eastern Area from a regional or national grid, and it was poised to receive gas from Midlands coal-gasification plants at any suitable point along the 12 in. high-pressure spinal main of the Cambridge divisional grid, which extends 35½ miles from Peterborough to a point near Sandy, and could be extended south to serve the new towns.

Such integration schemes as would show a requisite level of profitability had been completed, and 53 works out of a total of 92 at vesting day had been closed. A programme for the closing down of six more works had been accelerated as a result of the last increase in coal prices and increased labour costs occasioned by rises in basic rates and shorter working hours. It was inevitable, therefore, that future budgets would show a reducing demand for coal, and this trend was likely to continue unless the price of coal fell, or unless the Board could make a coke that would be so acceptable to the housewife that she would be prepared to pay a higher price for it and so improve the financial return on the carbonizing process as a whole.

Speaking of the production of "Gloco" and "Cleanglow", and the supply of pre-packed solid fuels, Mr. Dyde said : "You will gather that coke, not gas, is now the main product in the carbonizing process, and it is on our ability to sell a quality coke at a remunerative price that the future life of local carbonizing plants will be determined".

The second line of attack in improving the Board's competitive position was the never-ending search for additional economy in all other departments of the Board's business ; and this led to the formation of an Organization and Methods Department charged with the task of standardizing the work on problems of organization, systems and productivity. In all the assignments it undertook, the department sought to simplify the organization, office and paper work, to eliminate unproductive work and maintain systems and methods in line with the Board's needs.

Since the inception of this Department, about 30 varied assignments in offices, works and on the district, had been undertaken. A major task was the examination of the method of operating the services of district gas fitters, and the first survey showed clearly that productivity could be increased by method study alone if the handling of appliances and fittings could be simplified, depot time reduced and a greater degree of mobility afforded to fitters.

It became apparent also that service to customers needed improvement, and thinking had been directed towards discovering a method whereby the delivery of appliances and fittings to customers' houses would coincide with the arrival of the fitter, and disconnected appliances and the debris of the job be removed on the same day.

Methods were studied, and eventually a scheme known as the "Fitter-Chargehand-Driver System" was evolved, which experience so far indicated combined the highest standard of service with the lowest cost.

This was now being supplemented by a study of maintenance and emergency work, in which the use of short-wave radio was being tested.

The strategic siting of service centres was examined also, and on the former Tottenham Division six centres, all in a small semi-circle, and three outer centres, were being amalgamated. These, and the central stores, would be replaced by centres for the three new larger districts. The first, the model for subsequent service centres, was being established at Harlow.

In another field, the work of coke delivery crews had been studied and an incentive scheme agreed that in one district had increased productivity by from 16 per cent to 24 per cent.

Interesting developments were also taking place in connexion with maintenance, clearing and laying of service pipes. A pilot scheme was being tried out using self-supporting gangs equipped with their own small units of road-breaking and backfilling equipment and a small vehicle driven by one of the gang.

The method of laying and relaying services, including the use of plastic pipe, was also being studied, and it was hoped eventually to introduce an incentive scheme for this work.

On the administrative side, there was a planned programme for surveys of all the Board's offices, and those so far dealt with had yielded staff reductions of between 16 per cent and 20 per cent.

A survey of the electronic billing unit, including the machine and clerical sections and the regional offices supporting them, was to be undertaken this summer. This would be followed by a reassessment of the staff and the setting up of the ultimate establishment.

As a result of all this activity in the administrative and operational fields, the Organization and Methods Department had demon-

strated savings estimated to amount to £300,000/a by March, 1964, and of this a saving of £138,000/a had already been realized.

As a third means to efficiency, Mr. Dyde said that the Board's competitive position could be improved by using more efficient appliances. It was the cost of the useful therm that mattered.

There had been some notable improvements in appliance design and performance, the most significant having been the development of convector room heaters. The most efficient of these gave 20 per cent more useful heat than an essentially radiant fire. This represented to the customer a saving of 6*d.*/therm.

" Are we, and our salesmen, taking full advantage of such developments? Is there sufficient research on improving appliance efficiency?", asked Mr. Dyde.

In the industrial field, there were developments that opened up almost unassailable new markets for gas, the best example being furnaces heated by high-velocity gas burners, in which the heat source was taken to the vessels or objects to be treated.

Besides improving appliance efficiency, there were other developments that opened up new markets—balanced-flue and Se-Duct venting, for example, and the former had not yet been sufficiently exploited.

After all the considerations for improving efficiency that he had mentioned—new sources of gas, organizational efficiency, appliance efficiency—the effectiveness of the Board's marketing policy ultimately determined the extent of its success.

The problem of how best to employ manpower and investment over the widening range of markets was of major importance.

Market research revealed a considerable diversity of market, and in determining priorities there remained much scope for business acumen and intuitive judgment.

JUNIOR GAS ASSOCIATIONS

Eastern Junior Gas Association

"A Safe Place of Work", *by B. J. Fuller, A.M.I.Gas E., Safety Officer, Eastern Gas Board.*

Paper delivered at Hitchin on 8th March, 1961.

This paper outlines the approach to the problem of accidents in the gas industry, analyses reportable accidents in the gas industry during 1959, and gives general rules for the prevention of accidents.

Details are given of locations on works where accidents may occur, and the recommendations for elimination of hazards at the points detailed. The appropriate Factories Acts and I.G.E. Recommendations are quoted in many instances, the physical aspects of a safe place of work being stressed throughout the paper.

Discussion and Replies

Mr. D. A. Cronin (Safety Officer, West Midlands Gas Board) congratulated the Author on his paper and commented that he had been kind-hearted. Referring to page 1, paragraph 3, of the paper, " this sombre picture ", he said, was reflected mainly in its cost to industry, and stressed how badly the gas industry compared with other industries. The gas industry well knew how to cope with catastrophes, but fell down on preventive measures. The gas industry was the third worst industry for accidents in this country, the other two being the coke oven and iron castings industries respectively.

The **Author** thanked Mr. Cronin for his contribution, and mentioned Mr. Cronin's book " Safety Recommendations in the Gas Industry ", also that Mr. Cronin had been a factories inspector before coming into the gas industry. The Author commented that there had been some improvement since the adoption of the I.G.E. Recommendations, but there still were " run-of-mill accidents " causing troubles ; hence the purpose of this paper.

Mr. B. Santo (Peterborough) thought that the Author had produced a comprehensive paper that would make those responsible for safety measures check over the various items listed. He commented that " the total cost to the nation and industry of one industrial injury at £231 " was an " eye-opener ".

In his opinion, a safety handbook for the use of workers was a necessity. He commented on the " wrong " and " right " ways of lifting, and stated that in the Royal Engineers each man was allocated a maximum load of 100 lb and that no muscle strain accrued by having both legs together. No mention was made in the paper of lifting by two men side by side.

The **Author** was of the opinion that a strict programme of safety training sometimes tended to multiply accidents ; also, accidents tended to increase, due to a lowering of morale, when a labour force was reduced. He agreed that a safety handbook was highly desirable. The Author disagreed with the suggestion that both feet should be together when lifting a load, and pointed out that in his opinion better balance could be achieved with the feet slightly apart and with one foot slightly forward of the other. The importance of team lifting should not be minimized, in particular the even distribution of muscle strain.

Mr. D. G. Simpson (Watford) drew attention to the issue by one member of the motor industry of a handbook to new employees and contractors, and said that a pass would not be issued to a contractor unless he had signed a satement that he had received and read the safety regulations. Mr. Simpson wondered whether the gas industry should apply the I.G.E. Safety Recommendations in similar fashion to contractors employed by it.

The **Author**, in thanking Mr. Simpson for his contribution, said that he gathered that he referred to the Vauxhall Motor Company, which two years ago was awarded the highest trophy in its accident prevention field.

Mr. R. E. P. Hoskin (Norwich) said it was the duty of contractors to ensure that plant installed by them complied with the Regulations, and he suggested that the Local Factory Inspector should be invited to inspect plant during installation. At Norwich, a weekly maintenance meeting was held at which a " safety forum " had proved useful in high-lighting possible hazards and avoiding further accidents.

The **Author** stated that the present Regulations were not very stringent about plant being installed, and commented that new Regulations covering this point were on the way. In his opinion, the guarding of plant should be to the requirements of the gas industry and not to those of the contractors. As the factories inspectorate was understaffed, it was virtually impossible for an inspector to visit frequently all the factories in his district. The idea of a safety forum was commendable, especially as the casual observer could not get real information.

Mr. H. J. Blakeley (Watford) enquired whether steps were being taken to ensure that contractors observed the Regulations.

The **Author** agreed that it was time suitable steps were taken in this direction, and commented that the " business of design was a vexed one ". He continued by saying that with Eastern Gas Board centralization standards should improve, and suggested that particular attention should be brought to bear on " packaged plants ".

Mr. R. L. Smith (Colchester) thought this was an important paper, and asked three questions :—

(1) Can the design of guards be improved?

(2) What are the Author's views on the purging of purifiers by steam?

(3) Is it better to fit one or two blow-down valves on a boiler?

The **Author** gave the following answers to Mr. Smith's questions :—

(1) There is room for improvement in guard design ; for example, a V-belt drive enclosed on three sides, but the back left open, should be totally enclosed. Chain drives could be protected and lubricated at the same time by fitting an oil-bath-guard, which would enhance the life of the chain and decrease maintenance.

(2) Steam is not a suitable medium for purging large vessels, but would be of use in a detarrer for removing light oils, *etc.* Inert gases are the real answer, and we must get used to them.

(3) Two valves are most desirable, but modern thought considers only one is necessary ; there is no legal requirement insisting on two valves.

Mr. W. F. Pritchard (Watford) considered that this was a paper that every engineer would wish to keep before him. With regard to the principles of accident prevention, he drew attention to the appearance of " training " last in the list. Using the illustration of an acrobat learning to fall correctly to avoid accident and injury, he suggested that training should be used to arrive at the fundamental principles of safety ; also, that there should be an awareness of the necessity of thinking before acting. Training should be coupled with pride in one's job ; " How can I do this job well and with safety "? should be everyone's personal question.

The **Author** thanked Mr. Pritchard for his observations on training, and emphasized that training for general purposes only was a good thing.

Mr. I. F. Miller (Southgate) congratulated the Author on his useful paper, and quoted his own experiences when purging a cast iron purifier. The plates in the next box cracked, which meant two boxes to empty, instead of one. In his opinion, the paper should have been entitled " A Safe Place to Work both Day and Night ", and he mentioned the haphazard lighting to be found on some works. Could the Author, he asked, give some information about the availability of lighting equipment? Would he give his views on the safety conditions applying to steeplejacks? He referred to Mr. Cronin's remarks on safety, and asked : " How do we compare with other industries in training and safety "?

The **Author** said that Mr. Miller's unfortunate experiences with the steam purging of cast iron purifiers were interesting and illustrated the hazards when using this medium. The lighting of works was vitally important and highly desirable. In answering Mr. Miller's question on steeplejacks, he said that " their job is such that it enjoys a special exemption from the Building Regulations, but only one learner is allowed on any one job, and each steeplejack is responsible for his own apparatus ". He drew attention to the danger of " our men " attempting to follow the steeplejacks' methods of working, thereby endangering their safety. He stated that I.C.I. had " a big and elaborate safety set-up with complete lists of Safety Recommendations ".

Mr. D. A. Cronin commented that it was a fact that not all Area Gas Boards had Safety Officers, and stated that Parkinson and Cowan had two full-time Safety Officers to 2,500 workpeople.

Mr. E. W. Bird (Chelmsford) enquired about contract boiler and detarrer inspectors and the regulations.

The **Author** commented that boiler and detarrer inspectors were competent persons in their own right, and unlikely to enter plant in an unsafe condition.

Mr. W. J. Spiller (Cambridge) congratulated the Author on his paper, and drew attention " to something which happens regularly —the importation of unsafe chains, *etc.*" The paper did not cover electrical safety to any extent. With regard to guards, Mr. Spiller was of the opinion that a " safety " clearance should be obtained before the contractor left the site.

The **Author** thanked Mr. Spiller for his contribution, and commented that a great deal of care was now taken to tidy up blatant cases of bad electrical installation, especially flameproof fitments to which always should be fitted comparable conduit. He concluded by remarking that " access for the maintenance of plant should be adequate ".

Wales and Monmouthshire Junior Gas Association

"Modern Management", *by A. Facer, F.C.I.S., M.I.Gas E., M.Inst.F., General Manager and Engineer, Pontypool Undertaking, Wales Gas Board.*

Paper delivered at Newport (Mon.) on 9th January, 1961, and at Rhyl on 8th February, 1961.

This paper, in which the Author states his " intention to limit " its scope to those aspects of management undertaken by the Executive Officer—the Manager, considers the subject under three main headings : (1) " The Functions of Management ", stated as " to review change, to organize for change, to communicate, to educate and to deal with problems " ; (2) " The Application of Management Functions ", under which the Author deals with expansion, staff organization, buildings, sales and consumer satisfaction, and (3) " Communications " within the undertaking. Each section is appropriately sub-divided, and the paper is illustrated by reference to the rapid expansion and development of the Pontypool undertaking of the Wales Gas Board.

The paper gives a short list of books recommended for further study of the subject, as well as appendices dealing with standard job codings for cookers, fires and water heaters respectively. A final appendix details the apprenticeship training scheme in gas fitting of the Pontypool undertaking between 1st August, 1960, and 31st July, 1961.

This paper, having been presented to joint meetings with the Wales Gas Sales and Service Association, contains a balance of interest between the technical and commercial aspects of modern management.

Forthcoming Meetings

The following meetings have been arranged for the six weeks commencing 1st September, 1961:

(a) District Sections and an Affiliated Association

THE INSTITUTION OF GAS ENGINEERS—EASTERN SECTION

12th October — Visit to Texas Instruments, Limited, Bedford.

THE INSTITUTION OF GAS ENGINEERS—LONDON AND SOUTHERN SECTION

17th October — Annual General Meeting. Paper, "The Organization and Operation of a Distribution Department", by W. E. Medhurst. (2.45 p.m. The Caxton Hall, Caxton Street, London, S.W.1.)

THE INSTITUTION OF GAS ENGINEERS—MANCHESTER AND DISTRICT SECTION

29th September — Visit to Car House Works, Rotherham. (10.30 a.m. to 4.15 p.m.)

THE INSTITUTION OF GAS ENGINEERS—MIDLAND SECTION

12th October — Autumn Meeting.

THE INSTITUTION OF GAS ENGINEERS—NORTH OF ENGLAND SECTION

5th October — Film Show on subjects of general interest to gas engineers. (The Lecture Room, Distribution Centre, Northern Gas Board, Valley Street, Darlington, County Durham.)

THE INSTITUTION OF GAS ENGINEERS—SOUTH WESTERN SECTION

18th October — Luncheon. (12.30 p.m. for 1 p.m. The Royal Hotel, Bristol.) Annual General Meeting and Chairman's Address. (2.30 p.m. South Western Gas Board, Radiant House, Bristol).

THE INSTITUTION OF GAS ENGINEERS—WALES AND MONMOUTHSHIRE SECTION

12th October — Annual General Meeting. (The South Wales Institute of Engineers, Park Place, Cardiff.) Luncheon. (The Park Hotel, Cardiff.)

THE SCOTTISH ASSOCIATION OF GAS MANAGERS

14th September — Centenary Annual General Meeting. Presidential Address by D. Beavis. William Young Memorial Lecture: "William Young in Practice and in Theory", by Dr. J. Burns, G.M. Film, "The Murton Coking Plant", introduced by H. Millner and C. Kuttner. Paper, "An Eye to the Future", by M. R. Bone. (9.30 a.m. The Music Hall, George Street, Edinburgh.) · Centenary Luncheon, by invitation of the Chairman and Members of The Scottish Gas Board. (12.45 p.m. for 1 p.m. North British Hotel, Edinburgh.) Civic Reception, by the Lord Provost, Magistrates and Council of the City and Royal Burgh of Edinburgh, followed by a Dance. (8 p.m. prompt, Assembly Rooms, George Street, Edinburgh.)

(b) Junior Gas Associations

EASTERN

23rd September — Presidential Meeting. Visits to the Cathedral, Strangers Hall and the Bridewell Museum. (Norwich.)

LONDON AND SOUTHERN

6th October — General Meeting. Presentation of awards. Induction of new President. Presidential Address. (Westminster Technical College, Vincent Square, London, S.W.1.)

12th October — Visit to the East Greenwich Works of the South Eastern Gas Board.

MIDLAND

10th October — Presidential Address.

SCOTTISH (EASTERN)

9th September — Joint Visit with West of Scotland Junior Gas Association to the Lurgi Plant, Westfield, Fife.

SCOTTISH (WESTERN)

1st September — Presidential Address by A. M. Jackson. (6.30 p.m. The Scottish Gas Board, Industrial Section, 9, George Square, Glasgow.)

9th September — Joint Visit with East of Scotland Junior Gas Association to the Lurgi Plant, Westfield, Fife.

6th October — Paper, "Work Study in The Scottish Gas Board", by G. Thomson. (6.30 p.m. Scottish Gas Board, Industrial Section, 9, George Square, Glasgow.)

WESTERN

14th October — Annual General Meeting and Presidential Address. (Bath.)

(*c*) Kindred Bodies

The following meetings of kindred bodies have been arranged for September, 1961. Members of The Institution of Gas Engineers who wish to attend any of these meetings, but are not members of the bodies concerned, should apply to the appropriate Secretary at the address indicated.

THE INSTITUTE OF FUEL

(18, Devonshire Street, Portland Place, London, W.1.)

21st September	Joint Meeting with The Institution of Plant Engineers. Paper, "Shell Boiler Developments", by G. Gunn. (7.30 p.m. Blackburn.)

THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

(14, Belgrave Square, London, S.W.1.)

21st and 22nd September	Joint Conference with the British Radiospectroscopy Group on Radiospectroscopy of Solids. Guthrie Lecture on "The de Haas-van Alphen Effect and the Electronic Structure of Metals", by Dr. D. Shoenburg, F.R.S. (The Physics Department, University College of North Wales, Bangor.)
28th and 29th September	Conference on The Physics of Gas Discharge Devices. Introductory Address by Professor J. D. Craggs. (The Regent Hotel, The Parade, Royal Leamington Spa.)

THE INSTITUTION OF PLANT ENGINEERS

(2, Grosvenor Gardens, London, S.W.1.)

5th September	Paper, "Corrosion—Prevention by Cathodic Protection", by R. A. Lowe and J. S. McLachlan. (7 p.m. Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2.)
6th September	Paper, "Gas in Industry", by L. A. Lush. (7.30 p.m. The Grand Hotel, Leicester.)
14th September	Paper, "Insurance and the Plant Engineer", by J. H. Oswald. (7 p.m. Roadway House, Oxford Street, Newcastle-upon-Tyne, 1.)
20th September	Paper, "Timber—Its Uses and Characteristics in Plant Engineering", by R. P. Woods. (7 p.m. South Eastern Gas Board Lecture Hall, 95, High Street, Rochester.)
21st September	Paper, "Shell Boiler Developments", by A. D. C. Gunn. (7.30 p.m. Castle Hotel, Blackburn.)
25th September	Paper, "The Construction of Bradwell Heat Exchangers", by J. Shaw and G. Cain. (7.30 p.m. The Houldsworth School of Applied Science, The University, Leeds, 2.)
26th September	Paper, "Industrial Use of Gas", by W. H. Tarn. (7.30 p.m. The South Wales Institute of Engineers, Park Place, Cardiff.)
28th September	Paper, "The Natural Ventilation of Industrial Buildings", by F. E. Grandidge. (7.15 p.m. The Exchange Hotel, Liverpool.)
28th September	Paper, "Industrial Relations", by W. Carron. (7.30 p.m. The Grand Hotel, Sheffield.)
29th September	Paper, "The Planning, Application and Maintenance of Industrial Lighting", by V. Heydon. (7.30 p.m. The Imperial Hotel, Temple Street, Birmingham.)

THE SOCIETY OF INSTRUMENT TECHNOLOGY

(20, Queen Anne Street, London, W.1.)

4th September	Paper, "Automatic Gauge Control", by P. R. A. Briggs. (7 p.m. Department of Fuel Technology, University of Sheffield, Mappin Street, Sheffield.)
8th September	Forum on Instrument Maintenance. (6.30 p.m. Lecture Theatre, Byng Kendrick Suite, Gosta Green College of Technology, Aston Street, Birmingham.)
13th September	Conference: "The Application of Instrumentation to Industrial Processes". (9.30 a.m. Loughborough College.)
26th September	Paper, "Underground Gasification of Coal", by Dr. A. E. Balfour. (6.30 p.m. Manson House, 26, Portland Place, London, W.1.)
27th September	Paper, "Analytical Instruments for Process Control", by E. J. West. (6.45 p.m. Welsh College of Advanced Technology, Cathays Park, Cardiff.)
27th September	One-day Symposium. "New Techniques in Primary Measuring Methods". (Kenwood Hall, Sheffield.)

Institution Register

Transfers

(*a*) **To Membership :**

Barrington, Albert Henry, Manchester.
Finnigan, John Rae, Bradford.
Morris, John Edward, Guernsey.
Murray, Graham Francis James, B.Sc., London.
Olsen, Norman, Southport.
Tatham, Frank Chennel, Kenley.
Wharton, Raymond Hope, London.

(*b*) **To Associate Membership :**

Swindells, Eric, B.Sc., Wilmslow.

Admissions to Studentship

Bullen, Andrew Reginald, Sheffield.
Gillett, Michael John, Richmond.
Jones, Austin Brian, London.
Stokes, James Barry, Bromley.

Deaths

The Council regrets to announce the death of the following Members of the Institution:

Bain, John (Kingston-on-Thames) M.1947 ; died 8th July, 1961.
Bingham, James Herbert (Lowdham) M.1932 ; died 11th June, 1961.

Library Accessions

The following are a few additions to the Library since the issue of the *Journal*, Vol. 1, No. 8, August, 1961:

American Gas Association:

High-pressure Hydrogasification of Petroleum Oils, by E. B. Schultz, *Jr.* and H. R. Linden. Institute of Gas Technology, *Research Bulletin 29*, 1960.

High-speed Oven Design and Baking Studies—Part 2: The Celeriter Oven, by D. M. Spinell. *Research Bulletin 85*, 1960.

Investigation of Entrainment Separation, by K. T. Semrau, 1961.

17th Annual Report of The British Coke Research Association, 1960.

Auckland Gas Company, Limited, Annual Report and Statement of Accounts, 31st March, 1961.

British Ceramic Research Association:

Co-operative Measurement of the Permanent Linear Change on Reheating of High-temperature Insulating Refractories, by J. F. Clements, J. Vyse and D. C. Beech. *Technical Note* 14, 1961.

Research and Ceramics, 1959—Section B: Fundamental Research of Ceramic Importance, by F. Vaughan, A. E. Dodd and F. Moore.

Research and Ceramics, 1959—Section G: Refractories, by J. F. Clements, T. A. Ingles and H. M. Richardson.

Research and Ceramics, 1959—Section H: Testing, by D. G. Beech, H. Bennett and R. P. Eardley.

British Standard 1016: Part 13: 1961 (Methods for the Analysis and Testing of Coal and Coke, Part 13: Tests Special to Coke).

British Standard 1991: Part 2: 1961 (Recommendations for Letter Symbols, Signs and Abbreviations, Part 2: Chemical Engineering, Nuclear Science and Applied Chemistry.

British Standard 1991: Part 3: 1961 (Recommendations for Letter Symbols, Signs and Abbreviations, Part 3: Fluid Mechanics).

British Standard 1991: Part 4: 1961 (Recommendations for Letter Symbols, Signs and Abbreviations, Part 4: Structures, Materials and Soil Mechanics).

British Standard 1991: Part 5: 1961 (Recommendations for Letter Symbols, Signs and Abbreviations, Part 5: Applied Thermodynamics).

British Standard 2972: 1961 (Methods of Test for Thermal Insulating Materials).

British Standard 2978: Part 2: 1961 (Measurements of Smoke Emission from Industrial Boilers, Part 2: Coal-fired Shell Boilers with Various Types of Mechanical Stokers).

British Standard 3250: Part 2: 1961 (Thermal Testing of Domestic Solid-fuel-burning Appliances with Convection, Part 2: Hood Method).

British Standard 3376: 1961 (Specification for Open Fires with Convection with or without Boiler).

Careers in Fuel. (The Institute of Fuel.)

Chemistry for Engineers. An Introductory Course, by E. Cartmell. (Butterworths, 1959.)

Epoxy Resins. Their Applications and Technology, by H. Lee and K. Neville. (McGraw-Hill, 1957.)

Fire Prevention, 1960, being the Annual Report and Chairmen's Statement of the Fire Protection Association.

Industrial Finishing Year Book, 1961.

Institution of Mechanical Engineers, Proceedings of the Automobile Division, 1959-60.

Iron and Steel Annual Statistics, 1960. (Iron and Steel Board and the British Iron and Steel Federation, 1961.)

Mellon Institute Annual Report, 1960.

Register of the Gas Industry, 1961. (Gas Publications, Limited.)

Research Review of the Commonwealth Scientific and Industrial Research Organization (Australia), for the Year Ending 30th June, 1960.

Temperature Measurement and Control, by W. F. Coxon. Heywood, 1960.

Tercentenary Celebrations of The Royal Society of London, 1960, edited by Sir Harold Hartley.

Abstract of Paper to a Kindred Body

From time to time, the *Journal* will publish abstracts of papers that, although not presented at meetings of The Institution of Gas Engineers, its District Sections or Affiliated Associations, are of general interest to gas engineers. Complete copies of such papers will be available for consultation or loan from the Library of the Institution.

Following is a synopsis of a paper presented to the 120th General Meeting of The Institution of Mining Engineers, at Nottingham, on 19th July, 1961.

"The Related Technologies of Coal Production and its Utilization",

by D. T. A. Townend, C.B.E., Ph.D., D.Sc., D.I.C., F.R.I.C., Hon.M.I.Gas E., F.Inst.F., (Director-General), and R. L. Brown, M.A., F.Inst.P., F.Inst.F., M.I.Chem.E., (Director of Basic Research Laboratories), British Coal Utilisation Research Association.

The various uses of different types of coal in relation to mining production are discussed, and the main inland disposals of coal by size grade to power station boilers, coke ovens, gas works (including total gasification), railways, general industry and the domestic market, are summarized. The progressive increases in the use of mechanical firing in industry and of pulverized fuel in power stations are not out of line with current trends in the production of small coal ; and in this connexion the mechanisms of coal breakage and of pulverizing are reviewed. In considering the supply of fuel to consumers, consistency—particularly in size distribution as well as in mineral matter—is of over-riding importance ; this is stressed in relation to combustion efficiency, automatic control, grinding, and the behaviour of mineral matter whether disposed as ash or slag. Consistency is of special importance to the smaller consumer.

A brief description is given of current investigations within the British Coal Utilisation Research Association into medium-sized industrial boilers ; this covers automatic operation using an improved chain-grate stoker together with integrated mechanical handling of coal and ash ; it is contended that coal can compete with oil only if industrial boilers can offer comparable amenities and labour saving.

A better understanding of the behaviour of the mineral matter in coal in relation to the mineralogical constituents is now considered to be of not less importance than that of the coal substance itself ; a section is therefore devoted to Minerals, Slag and Ash. Within this ambit current investigations concerned with deposits and corrosion in water tube boilers (Boiler Availability) are summarized, and the concluding sections are concerned with the future trends in coal utilization together with the major areas of scientific and technical ignorance with which the development engineer is currently faced.

It seems reasonable to predict that gas and electricity will play an increasingly important part in industry and in the home and that they will provide the major outlets for coal in addition to anthracites, coke and smokeless fuels. Gas, if cheap enough, has advantages over other fuels ; it causes negligible atmospheric pollution, and users' plant can readily be made flexible, efficient and automatic.

Intense effort to cheapen electricity made from coal is indicated, particularly an extension of current studies aimed at overcoming the problems arising from the presence of mineral matter in coal, both now and having in mind the coal supplies likely to be available in the future.

It is concluded that further advances in mechanization of mines and automation of coal-using equipment can meet the challenge of other fuels only if production, preparation and use are linked together more closely.

General Notices

Heating, Ventilating and Air Conditioning

The First International Conference on Heating, Ventilating and Air Conditioning is to be held at Olympia, London, from 27th September to 4th October, 1961. The conference, which is to be opened by Lord Mills, will have a section devoted to future sources of energy (including economics of supply of alternative fuels), in which Mr. W. K. Hutchison, C.B.E., M.A., B.Sc., M.I.Gas E., Deputy Chairman, The Gas Council, is to speak.

The overall Chairman of the conference will be Dr. F. M. H. Taylor, A.M.I.Gas E., who was recently elected President of The Institution of Heating and Ventilating Engineers and will deliver his Presidential Address to the opening session of the conference.

Further particulars may be obtained from the Secretariat of the Conference, The Institution of Heating and Ventilating Engineers, 49, Cadogan Square, London, S.W.1.

Symposium on Corrosion : Printed Proceedings

In September, 1960, the Society of Chemical Industry, through its Corrosion Group, organized with The Institution of Gas Engineers and The College of Advanced Technology, Birmingham, a Joint Symposium on "The Protection of Gas Plant and Equipment from Corrosion".

The eight papers read and discussed at the two-day Symposium and the discussions have now been published. Copies of the special publication are available from the Publications Department, Society of Chemical Industry, 14, Belgrave Square, London, S.W.1. The cost per copy is £1 but members of the Society of Chemical Industry, The Institution of Gas Engineers and The College of Advanced Technology, Birmingham, may purchase one copy each at the special price of 15*s*.

The titles of the papers are as follows :—

- "Electrochemical Principles of the Corrosion and Protection of Metals," by T. P. Hoar.
- "Organic Protective Coatings", by A. T. S. Rudram.
- "The Protection of Structural Steel Against Corrosion", by J. C. Hudson.
- "Cast Iron and Corrosion in the Gas Industry", by H. H. Collins.
- "Principles and Application of Cathodic Protection", by K. A. Spencer.
- "The Protection of Gas Service Pipes and Fittings", by A. D. L. Copp, W. J. Gooderham and E. Manners.

"Corrosion and the Gas Consumer", by F. C. Moody and C. H. Purkis.

"Sprayed Metal Coatings in the Gas Industry", by R. E. Mansford.

British Conference on Automation and Computation Inaugural Annual Lecture

Dr. D. G. Christopherson, O.B.E., F.R.S., Pro-Vice-Chancellor of the University of Durham and Warden of the Durham Colleges, has accepted an invitation to give the first annual lecture of the British Conference on Automation and Computation (B.C.A.C.), and will speak on the subject, "Mathematics—Friend or Foe?" at the Lecture Theatre of The Institution of Electrical Engineers, Savoy Place, London, W.C.2, on Wednesday 27th September, at 5.30 p.m.

The lecture is open to all members of the 31 member societies of B.C.A.C.; others should apply for tickets (free) from the Honorary Secretary, B.C.A.C., *c/o* The Institution of Electrical Engineers, Savoy Place, London, W.C.2. Tea will be served at 5 p.m.

Courses in Welding Technology

Courses in welding technology to be held in London in the autumn of 1961 are as follows :—

2nd to 6th October : Welded Pressure Vessels.

16th to 17th October : Residual Stresses and Stress Relief.

18th to 20th October : Practical Control of Distortion.

Further particulars may be obtained from the School of Welding Technology, 54, Princes Gate, London, S.W.7.

Current Practice in Fuel Efficiency

The Eighth Annual Refresher Course on Current Practice in Fuel Efficiency will be held at the Clarendon Laboratory, Oxford, from 25th to 29th September, 1961.

Further particulars of the course are obtainable from Mr. P. Snaith, National Industrial Fuel Efficiency Service, Ailsa House, 181, King's Road, Reading.

Domestic Heating and Insulation Exhibition

A Domestic Heating and Insulation-in-the-Home Exhibition is to be held in the Free Trade Hall, Manchester, on 19th to 22nd September, 1961.

33rd Congrès International de Chimie Industrielle

The 33rd International Congress of Industrial Chemistry is to be held at Toulouse and Bordeaux on 28th September to 8th October, 1961.

Further particulars of the Congress are obtainable from Société de Chimie Industrielle, 28, rue St.-Dominique, Paris, 8.

Standard for Letter Symbols, Signs and Abbreviations

Part 1 of a British Standard for letter symbols, signs and abbreviations, containing recommended symbols, signs and abbreviations for the fundamental quantities and units of interest to physicists, chemists and engineers was issued as B.S.1991 in 1954.

Parts 2 to 5 have now been issued to give recommended symbols for quantities and abbreviations for units in the fields covered by their titles, as follows :—

B.S.1991 : Part 2 : 1961 (Chemical Engineering, Nuclear Science and Applied Chemistry).

B.S.1991 : Part 3 : 1961 (Fluid Mechanics).

B.S.1991 : Part 4 : 1961 (Structures, Materials and Soil Mechanics).

B.S.1991 : Part 5 : 1961 (Applied Thermodynamics).

B.S.1991 : Part 1 : 1954 (General), was amended in October, 1960, by the issue of PD3920, which gives the more urgent modifications required to preserve the interconsistency of all five parts. A comprehensive revision of B.S.1991 : Part 1 : 1954 (General) will shortly be put in hand.

Copies of Part 1 (7*s.*), Part 2 (10*s.*), Part 3 (7*s.* 6*d.*), Part 4 (12*s.* 6*d.*) and Part 5 (7*s.* 6*d.*) may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1. (Postage extra to non-subscribers.)

Library

The Library and Reading Room of the Institution are open on weekdays between 9 a.m. and 5.30 p.m. Members may borrow books by post, excepting books of reference and certain others, on application to the Secretary.

Institution Necktie

The Council of the Institution, in response to a number of requests from members, has arranged for the manufacture of an Institution tie, which will enable members readily to identify other members they meet and with whom they associate both in work and socially.

The design incorporates a motif taken from the Institution's coat of arms and consists of a crown and two crossed torches. The tie is made of silk with the motif on a blue background.

In order that the sale of the ties shall be restricted to members of the Institution they will be obtainable only from the headquarters of the Institution or from district sections at 17*s.* 6*d.* each, post free. This price will enable a contribution of 5*s.* for every tie sold to be made to the Benevolent Fund of the Institution.

Orders may be addressed to the Secretary, The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1, and should be accompanied by the appropriate remittance.

Benevolent Fund

Contributions to the Benevolent Fund of the Institution may be paid at any time to the Honorary Secretary of the Benevolent Fund, 17, Grosvenor Crescent, London, S.W.1. It is a convenience if annual contributions are made by banker's order, and it is particularly advantageous to the Fund if such contributions are made by Deed of Covenant, whereby the Fund is able to reclaim from the Inland Revenue an appropriate sum in respect of income tax paid by the contributor. Further particulars, with deed forms and banker's orders for completion, are obtainable from the Honorary Secretary of the Fund.